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(54) **SOLAR HEATED BUILDING DESIGNS FOR CLOUDY WINTERS**

DURCH SONNENWÄRME GEHEIZTE GEBÄUDE-ENTWÜRFE FÜR BEWÖLKTEN WINTER

STRUCTURES DE BATIMENTS A CHAUFFAGE SOLAIRE CONCUES POUR DES HIVERS NUAGEUX

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(73) Proprietor: **CHAHROUDI, Day**
Placitas, NM 87043 (US)

(72) Inventor: **CHAHROUDI, Day**
Placitas, NM 87043 (US)

(74) Representative:
Cheyne, John Robert Alexander Mackenzie
Haseltine Lake & Co.,
Imperial House,
15-19 Kingsway
London WC2B 6UD (GB)

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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a continuation-in-part of U.S. Application, Serial Number 07/670,783, filed on March 19, 1991, corresponding to WO-A-9 216 702 and representing a state of the art under Art. 54(3)EPC and disclosing

a solar heated building having a solar collector (22),
the collector is formed from at least one panel comprising:
a layer of transparent glazing (26);
a layer of transparent insulation (30) with a thermal conductivity of less than 1 • 6W/m^2/°K (0.3 BTU/sq. ft./°F/hr);
a layer of optical shutter (36) located on one side of said transparent insulation (30), the optical shutter (36) having a maximum solar transmission three or more times greater in its transmissive state than in its opaque state; and
a layer of solar radiation absorbing material (40) with an adsorption of the solar energy spectrum of 70% or greater;

REFERENCE TO OTHER PERTINENT INFORMATION

[0002] This application is also related by subject matter to a paper entitled "Weather Panel Development And Architecture," to be delivered by Day Chahroudi on May 26, 1992, at the Transparent Insulation Technology Conference given at Freiburg, Germany, sponsored by the Fraunhofer Institute; and to a disclosure entitled "Solar Heated Building Designs For Cloudy Winters," dated May 19, 1992, also authored by Day Chahroudi. Both, the aforementioned paper and the disclosure, are incorporated herein by reference in their entirety, and copies thereof are attached to this application.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0003] The present invention is directed to an improved design for solar-heated buildings. In particular, the present invention relates to improved designs for solar-heated buildings that offer improved ease of building design and construction, lower cost, and better performance over existing passive solar heating designs, particularly in climates with cloudy winters.

2. Discussion of Related Art

[0004] A number of known systems have been used to collect, hold and release solar energy. Existing solar collectors typically collect solar heat during one to ten days per month of sunny winter weather. These existing solar systems store the collected heat only on sunny days and release heat during cloudy weather. A large proportion of the world's population lives where winters are cloudy. Previously, solar architects have responded with a design strategy of collecting solar heat during the one to ten days per month of sunny winter weather, and then storing this heat and releasing it during cloudy weather. This design suffers from several disadvantages. For example, this design necessitates that a full size backup fossil fuel heater be used when heat storage gives out during the longest periods of cloudy weather. It requires a large thermal storage unit which is expensive and which can lose some of the heat it stores, and it requires a large solar collector area which faces the equator, the direction of the winter sun, and in addition is more expensive. The solar collector must occupy most of a south facing wall and/or roof, which places severe restrictions on the building's shape, orientation and appearance. The above restrictions make the design of a conventional solar heated building a highly skilled compromise between conflicting requirements of aesthetics, building shape, use and site limitations, cost, and solar efficiency. Solar space heating and daylighting have not yet fulfilled their promise because reconciliation of the conflicting requirements of solar efficiency, low cost, ease of construction, aesthetics, building shape and site is difficult and often impossible.

[0005] Various similar building designs for collecting and storing sunlight have been used in the past. Nevertheless, none of these known designs have provided an efficient means for incorporating the solar collector in a building without altering the aesthetics, shape, orientation or functionality of the structural design, or, alternatively, without sacrificing solar collection efficiency. The conventional solar heating systems require large thermal storage units, and large equator-facing solar collectors typically placed on south walls of buildings.

[0006] None of the previously known systems described above offers the important advantage of the ability to efficiently collect and store sunlight on cloudy days. Similarly, none of the above-described art locates solar collectors on the building's roof when the roof design is dictated by architectural rather than solar conditions; instead, solar collectors

were located on the south walls or the roof of the building, thus requiring substantial modification of traditional building design and orientation.

SUMMARY OF THE INVENTION

[0007] It is an object of the present invention to maximize solar efficiency while eliminating the need for special building design plans or compromises on building aesthetics.

[0008] A further object of the present invention is to allow the substitution of roof elements or wall elements with solar collectors rather than to necessitate the addition to roof elements or wall elements, so that the cost of the roof is subtracted from the cost of the solar collector.

[0009] It is an additional object of the present invention to solve problems of location and orientation of solar collectors. Additional objects of the invention will become apparent to those skilled in the art from the following description thereof.

[0010] According to the present invention, there is provided a solar heated building having a solar collector, wherein

more than half of the solar collector area is provided by a roof collector forming part of the roof of the building, the solar collector having a maximum solar energy admittance of 30% or greater, and in that:
the roof collector is formed from at least one panel comprising:
a layer of transparent glazing;
a layer of transparent insulation with a thermal conductivity of less than $1 \cdot 6 W/m^2/°K$ (0.3 BTU/sq. ft./°F/hr);
a layer of optical shutter located on one side of said transparent insulation, the optical shutter having a maximum solar transmission three or more times greater in its transmissive state than in its opaque state; and
a layer of solar radiation absorbing material with an adsorption of the solar energy spectrum of 70% or greater;
the building further comprising:
one or more heat storage elements which store at least 70% as much heat a is necessary to heat the building overnight on the average day of the coldest month of the year where the building is located.

[0011] In one particular embodiment, the heat storage element is placed after the layer of the transparent insulation material, with respect to the direction of travel of the incident sunlight. The optical shutter is positioned adjacent to the transparent insulation material and in heat transfer relationship to the heat storage element and/or is placed between the glazing and the transparent insulation material. Alternatively, if the optical shutter is used as a reflecting means, the heat storage element may be replaced by a solar absorbing material. The term "heat transfer relationship" means that the heat storage element is placed in sufficient thermal contact to an element with which it is in such a relationship to transfer heat to that element. The heat may be transferred to the element by any suitable means, such as by convection, conduction or forced heat transfer, e.g., fans moving heated air throughout the building. The term "element" means any object within the building which is capable of absorbing heat, such as sheet rock, articles of furniture, potted plants, or any structural components of the building, such as interior brick walls or collection of stones.

[0012] Depending on climate, the multi-layered solar collector will be incorporated into the majority of a building's roof. Necessarily, the thermal conductivity of the transparent insulation material is less than $1 \cdot 6 W/m^2/°K$ (0.3 Btu/sq.ft./°F/hr.), and an additional layer comprising a solar radiation absorbing material with an absorption of greater than 70% of the solar energy spectrum is placed where it will absorb sunlight admitted by the optical shutter and transparent insulation. Also to meet terms of this invention, the optical shutter must transmit at least three times more solar radiation energy in its transparent state than in its opaque state.

[0013] In the context of the present invention "solar collector" means a solar energy admitting element including an optical shutter material which becomes opaque to prevent overheating of the panel. The solar collectors utilized herein are preferably high efficiency transparent insulation and optical shutter solar collectors (HETIOSSC). During cloudy and winter days, the HETIOSSC has sufficiently high solar transmission efficiency to collect sufficient solar thermal energy for heating the building on top of which they are placed.

[0014] As pointed out in greater detail below, the placement of the solar collector in the building's roof provides important advantages over the prior art. For example, by locating the solar collectors in the roof rather than in the side walls, the orientation and shape of the building do not dictate the building's solar performance. This greatly reduces the skill required to design an efficient solar heated building.

[0015] If placed incorrectly, these HETIOSSC merely turn into opaque insulating panels, thus design mistakes are not important. A further advantage of the present invention is that this design acts to substitute for conventional roof elements rather than adding to existing roof structure, thereby allowing the cost of a conventional roof to be subtracted from the cost of the solar collectors. Yet a further advantage of the present invention is that the insulation value and cost of implementing the present design are comparable (but not necessarily equal) to conventional roof construction so that parts of the roof may be replaced without great additional cost or nighttime heat loss. Accordingly, the need for a large

overnight backup fossil fuel (or other non-solar heating system) is obviated.

[0016] Yet another advantage of the present invention is the increased efficiency of collecting the comparatively dim and diffuse solar energy available during cloudy weather, even during the cold winter temperatures of northern latitudes, and that these solar collectors have both solar transmission and insulating value great enough to collect heat during cloudy weather.

[0017] The invention itself, together with further objects and attendant advantages, will best be understood by reference to the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

Figure 1 shows a building which incorporates a solar collector into the building's roof;
Figure 2 shows a cross-section of a building with the roof and solar collector indicated;
Figures 3A-3C show a cross-section of a solar collector using thermochromic shutter from the outdoor side (left) to the indoor side (right);
Figure 3D shows a ¾ view of a possible panel configuration;
Figure 4 shows schematically the relative positioning in a solar collector of the layer of transparent glazing material adjacent to the layer of absorbing optical shutter;
Figure 5 shows a typical optical shutter reflectivity response to ambient temperature. This Figure shows how solar radiation reflection varies with changes in temperature;
Figure 6 shows schematically the relative positioning in a solar collector of the layer of thermochromic reflective optical shutter to the layer of transparent insulation material and the optional solar radiation absorbing material;
Figure 7 shows schematically an alternate embodiment of the transparent insulation layer, in which one or two low emissivity layers are affixed to the interior surfaces of a glass-enclosed vacuum;
Figure 8 shows an alternate embodiment of the transparent insulation layer utilizing a honeycomb material;
Figure 9 shows schematically the honeycomb transparent insulation material with its openings approximately perpendicular to the structure's glazing and roof;
Figure 10 shows schematically an alternate embodiment of the honeycomb material with its openings oriented approximately perpendicularly to the building's floors;
Figure 11 shows schematically an alternate embodiment of an aerogel transparent insulation layer;
Figure 12A shows the various possible locations of all of the necessary and optional layers to the solar collector;
Figure 12B shows the identity of the various possible layers depicted in Figure 12A;
Figure 13 shows schematically several additional variations and placement of the beat storage element and possible location of evaporators and condensers of water;
Figure 14 shows schematically an example of transferring heat by means of air circulated by fans through ducts;
Figure 15 shows schematically an air-to-air heat exchanger including separate fans connected thereto which drive the air in both circulation loops;
Figure 16 shows schematically heat circulation with water, pipes and pumps;
Figure 17 shows schematically the manner of transferring heat from heat storage elements contained in the floor below the roof to the remainder of the building's interior by means of thermal radiation;
Figure 18 shows schematically placement and operation of a solar still;
Figure 19 shows the operation of an air-to-air heat exchanger; and
Figure 20 shows the framing detail of attachment of multiple solar collectors to the rafter of the roof of a building and the condensation channels for collecting distilled water.

DETAILED DESCRIPTION OF THE INVENTION

[0019] Turning now to the drawings, Figure 1 shows a building 20 which incorporates a solar collector 22 into the building's roof 24. This building's 20 design involves minimal adverse aesthetic or financial impact, and this particular example is a dwelling of four 150m^2 (1500 sq. ft.) apartments. The pitch of the roof 24 is 30 degrees, approximately the minimum angle at which snow will slide off. The roof 24 is made entirely from solar collectors 22, except for a fringe made of a traditional roof material. In its transparent state, a solar collector 22 transmits diffuse solar radiation (more precisely, hemispherical solar spectrum transmission) at a rate of more than 30%. Any solar collector/building configuration (the absorber and heat storage may be part of the building and not the collector, see Figure 13) which are capable of: solar transmission ≥ 30%; the ratio of the optical shutter's maximum:minimum transmission ≥ 3:1; solar absorbance of ≥ 70% of the absorber; storage ≥ 70% of overnight heat usage on average day of coldest month can be used in this invention. Suitable solar collectors are abbreviated herein as high efficiency transparent insulation and optical shutter

solar collectors (HETIOSSC). Preferred embodiments of the solar collectors made of such HETIOSSC are described in detail in WO-A-9 216 702, entitled "Light Admitting Thermal Insulating Structure," which application is attached hereto. For the sake of clarity, the term "convection baffle" in this application corresponds to the element identified as CBTLTR in the aforementioned '783 application. Briefly, the light admitting thermal insulating structure in that application comprises a light admitting thermal panel having improved thermal resistance which transmits light and solar radiation between the inside and outside of the panel, one or more transparent insulation layers (thermal radiation and convection suppressing materials) near the outside surface of the panel, and an optical shutter layer and optional solar radiation absorbing layer near the inside of the building. These HETIOSSC are designed to be placed on or form the roof or walls of the building to be heated.

[0020] The convection baffle is a structure designed to divide a gas filled cavity into compartments, and to thereby suppress convective heat transfer by the gas inside the cavity. The convection baffle, when used with a transparent low emissivity layer, can be made from thin sheets or films of a sunlight and thermal radiation transparent material. These baffle surfaces may be constructed from a polyolefin, preferably of very high crystallinity polyethylene, or very low crystallinity polyethylene.

[0021] The low emissivity layers are layers that either transmit or absorb light. These layers may include one or more coatings or layers of material which reflect and do not emit thermal radiation to prevent its transmission. They may be transparent or may absorb light. These layers are described further, infra.

[0022] The optical shutter is a layer which regulates light transmission, thereby preventing the flow of heat in the form of sunlight.

[0023] A shutter may be reversibly activated by local temperature (thermochromic), incident light intensity (photochromic), an electric current or field (electrochromic) or both local temperature and incident light intensity (thermophotochromic).

[0024] The optical shutter allows regulation of the desired solar heat, and thus the temperature for the area in which solar energy is to be directed or diverted.

[0025] U.S. Patent No. 4,085,999, issued on April 25, 1978 to Day Chahroudi, entitled "Transparent Thermal Insulating System," and U.S. Patent No. 4,307,942, issued on December 29, 1981 to Day Chahroudi, entitled "Solar Control System". These patents disclose some examples of optical shutters which can be used in solar collectors utilized in this invention.

[0026] In this invention (Figure 1), the solar collectors 22 are placed on the roof 24 rather than on a vertical wall of the building, for maximum solar heat collection, on cloudy days.

[0027] Turning now to Figure 2, a cross-section of an alternate embodiment of the building 20 is shown with the roof 24 solar collector 22 indicated. As shown in Figure 2, the building may be an inexpensive building, which may contain apartments or offices, for example. The roof 24 may be constructed at a 30 degree pitch or greater to allow snow to slide off. An insulation envelope 23 made from tunnel segments (not shown) of 200 feet (65 meters) wide may be used to limit span and snow build-up along the edges. The 65 foot (20 meters) height of the insulation envelope 23 facilitates summer cooling by catching wind and by the chimney effect. Included within the insulation envelope 23 of the building 20 is heat storage, consisting of anything interior to or contained within the opaque and transparent insulation of the building 20 and the ground it is built on. Thus, for example, a brick wall forming the outside surface finish (not shown) of the building would not be included, nor would the exterior transparent glazing of a skylight (not shown). Inside the sometimes translucent, sometimes transparent tunnel comprising the insulation envelope 23 are a few levels of rooms 25 which are stacked like bleachers. The ceilings above these rooms may be covered with gardens 26 which may be used to provide fresh food, water and air, and heat may be stored in the uninsulated structure of the rooms 25. A garden for the apartment above may be on the roof of the apartment below. This garden can be made private from next door gardens by trellis walls covered with plants or by shrubs. When this building design is not used for apartments, the roof gardens can be public, with the envelope moved a bit further from the rooms to make space for larger trees. Year round summer parks, gardens, athletic fields and swimming pools may be shaded by tall trees both between the rows of apartments, and where the envelope segments join or bend.

[0028] In Figures 3A-3C, there is schematically illustrated a cross-section of various embodiments of the HETIOSSC solar collector 22 made with low emissivity coatings, thermochromic shutter and convection baffles. In Figures 3A-3C, the layers are described in the direction from the outdoor side (left) to the indoor side (right). Figures 3A-3C show a layer of transparent glazing material 26, which is a material that transmits solar radiation, such as glass, plastic sheet or film or translucent fiberglass reinforced plastic. Adjacent to the transparent glazing material 26 is a layer of a transparent insulation material 30, which transmits solar radiation well but which does not transmit heat well, having a thermal conductivity less than 1 • 6W/m^2/°K (0.3 (BTU/ft^2/°F/hr.)). As used herein, the term "adjacent" means substantially parallel to but not necessarily touching another layer. The transparent insulation material 30 can be comprised of one or more low emissivity layers 32 and one or more layers 34 which perform the function of suppressing convection heat transfer, yet are transparent to solar radiation, as do low emissivity coatings and baffles, honeycombs, aerogels, and vacuum containing low emissivity coated windows. Suitable materials for the layer or layers 34 are convection baffles 34 or hon-

eycomb structures, evacuated windows, aerogels and multiple panes of anti-reflected plastic film or glass. The low emissivity layer or layers 32 are comprised of any material which transmits solar radiation while reflecting thermal radiation, for example, $In_2O_3/Ag/In_2O_3$, or other dielectric/metal/dielectric stacks made by vacuum coating or indium or tin oxide layers made pyrolytically. Next to the layers 34, there is a layer 36, which performs the function of optical shutter. The layer 36 is suitably made from a reflecting or absorbing optical shutter which is activated by voltage, current, heat or light. Next to the layer 36, there is a layer 37 (not shown separately) which performs the function of structural surface (protective layer) of the collector; it may be absorbing or transparent. The layer 37 can be made from any solid material, such as metal, plastic, glass, plastic film or fiber reinforcement plastic. The function of the layer 37 is to provide mechanical rigidity and protection to the collector and, optionally, to store heat.

[0029] Figures 3B and 3C illustrate alternative embodiments of the solar collector, which include four layers 34 (convection baffles). In these alternative embodiments, the solar panel is the HETIOSSC solar collector identified above

[0030] The transparent insulation material 30 has insulating values equal to one to two inches of plastic foam, which is comparable (but not necessarily equal) to the insulating value of a typical roof and wall construction. At the same time, such a high performance transparent insulation material transmits from 30% to 70% of incident solar energy.

[0031] Figures 7 through 11 exemplify the incorporation of various types of transparent insulation components in solar collector 22. In Figures 3A, 3B and 3C, the low emissivity layer 32 is a material which does not emit much (i.e., less than 25%) of room temperature thermal radiation in the wavelength range of 3 to 40 microns. The low emissivity layer 32 may be transparent and composed, for example of a thin silver layer which is anti-reflected (i.e., reflects less solar radiation) by two dielectric layers on each side, for example a layer of indium/tin oxide. The low emissivity layer 32 may be absorbing of solar radiation and be composed, for example, of a layer of nickel suboxide atop a layer of aluminum. If the low emissivity layers is absorbing, it is placed within the collector 22 and between the convection baffle 34 and the interior of the building 20. The convection baffle is preferably a layer of a material which absorbs less than 25% of thermal radiation between 3 and 40 microns wavelength. An example of a suitable material used for the convection baffle 34 is a 0.001 inch thick polyethylene film. The convection baffles 34 double the thermal resistance of a solar collector 22 (as compared to one without convection baffles) and they are inexpensive. If the aforementioned polyethylene material is used as the convection baffle it, unlike most plastics, is 90% transparent to long-wave infrared radiation between 3 and 40 microns wavelength, and it is extremely transparent to sunlight and can endure the sun's ultraviolet rays for 30 years. If the convection baffles 34 absorb too much radiation, they would undermine the effectiveness of the low emissivity layer 32. The use of convection baffles 34 can double the insulating value of a low emissivity layer 32 but represents a fraction of the cost of a second low emissivity layer 32. Figures 3A-3C show how a transparent insulation may be installed in a solar collector 22. Adjacent to and on either side of the transparent insulation material 30 is a layer comprising an optical shutter 36 which includes a material or device with controlled reversibly variable transmission of solar radiation and which transmits three or more times as much solar radiation energy in its transparent state as in its opaque state. Solar energy transmission through the optical shutter 36 may be controlled by temperature (i.e., see Figure 5), by electrical means such as current or voltage, or by mechanical action, for example, and may block solar radiation through reflection or absorbance. The optical shutter's 36 placement will depend on whether the optical shutter 36 in Figure 12 is functioning as a reflective or absorbing means.

[0032] When it is the absorbing type of shutter, the optical shutter 36 is positioned between and adjacent to both the transparent glazing material 26 and the transparent insulation material 30 (see Figure 4). When utilized as a reflecting means, the optical shutter 36 is positioned either adjacent to transparent insulation material 30 or the optional heat storage elements 42 or, if present, an optional layer of solar absorbing material 40 (as shown in Figure 12).

[0033] Figure 3C illustrates yet another alternative embodiment of the solar collector using a low emissivity type transparent insulation, which also incudes seven layers separated from each other. This solar collector may also include a layer of a solar absorbing material 40. This solar absorbing material 40 includes, for example, dark paint to absorb radiation and to match the building's 20 exterior and, for example, an interior finish of a layer of wallpaper, plaster or wood which gives the interior of a building 20 a pleasing appearance and/or is easy to clean.

[0034] By way of example, the relative thermal conductivity and solar transmission of the three exemplary solar collectors in Figures 3A-3C may be as follows:

TABLE

FIGURE	3A	3B	3C
THERMAL CONDUCTIVITY WATT/M$^{2\circ}$C	1.1	0.57	0.57
BTU/FT$^{2\circ}$F	0.20	0.10	0.10
TRANSMISSION SOLAR, %	70-7	50-5	50-5

[0035] Solar transmissions and thermal resistances in the above Table were calculated using the Window 3.1 program from USDOE Lawrence Berkeley Laboratory. Most of these values were also measured by the Fraunhofer Institute in Freiburg, Germany; ISFH in Hanover, Germany; and BBRI in Brussels, Belgium. The measurements confirmed the computer model in every case. The high values listed above for solar transmission of the solar collector 22 in Figure 3A suggest its use in a greenhouse. The high thermal insulation values above for the solar collector 22 in Figures 3B-3C suggest its use in collecting heat during cloudy days.

[0036] Figure 4 shows greater cross-sectional detail of the relative positioning in a solar collector 22 of a layer of absorbing or reflecting-type optical shutter. A transparent glazing material 26 is adjacent to the layer of an absorbing or reflecting optical shutter 36, which in turn is adjacent to the transparent insulation material 30, which, in this embodiment, is adjacent to the optional solar absorbing material 40. This figure illustrates a structural arrangement of various layers which are necessitated by using an optical shutter 36 which functions by absorbing means. When an optical shutter 36 becomes absorbing and heats up it must be insulated from the building's interior by transparent insulation 30. Thus, an absorbing-type optical shutter 36 should be located between the glazing 26 and the transparent insulation 30. If the optical shutter 36 is a reflecting type, it may be placed on either side of the transparent insulation 30.

[0037] As shown in Figure 5, the thermochromic reflective type optical shutter's 36 reflectivity response to ambient temperature is plotted against the ambient temperature. This Figure shows how solar radiation reflection varies with changes in ambient temperature for a thermochromic reflective optical shutter of Figure 6, located next to the building's interior or thermal storage in order to maintain constant the buildings interior or thermal storage temperature.

[0038] Variations on the embodiments described above are possible. For example, Figure 6 shows a cross-sectional view of a solar collector 22. In Figure 6, a layer of a transparent glazing material 26 is adjacent to a layer of transparent insulation material 30, which, in this embodiment, is adjacent to a layer of the reflecting optical shutter 36, which, in turn, is adjacent to the optional solar absorbing material 40. Figure 6 also shows how a reflective optical shutter, such as Cloud Gel, may be installed in a solar collector 22. Cloud Gel is a thermochromic reflective optical shutter and it is a trademark of Suntek, Inc. Other materials may be used as a reflective optical shutter in the solar collector used herein. See also, "Thinking Window Switches Off the Sun When it is Hot," Popular Science, March 1984, and my article "Contractor Designed Passive Heating, Cooling, and Daylighting," U. S. Passive Solar Conference (March 1990).

[0039] Briefly, Cloud Gel is a thermo-optical shutter layer consisting of a polymer and a solvent, where the polymer precipitates reversibly from the solution above its transition temperature, thereby reflecting light. The polymer and the solvent form separate phases which are finely divided. One of the phases is solvent rich, while the other phase is polymer rich.

[0040] The optical shutter 36 provides shading in the solar collector 22 to prevent overheating the building, as the temperatures in the collector can reach up to 400°F without concentrating sunlight. Cloud Gel, a thermochromic optical shutter, reversibly turns an opaque white color and reflects up to 90% of the entire spectrum of solar energy when heated above comfortable room temperature, and then returns to a clear state with 90% solar transmission when cooled. The transition temperature and the maximum reflectivity can be set during manufacture to create a variety of indoor climates for people and plants.

[0041] Merely by way of example, other types of optical shutters 36 can be activated by electronic current or voltage. These optical shutters 36 are categorized as electrochromic and can be controlled to have the properties of absorbing or reflecting solar radiation. The optical shutters can be controlled with electric voltage or current. Figure 4 shows how an absorbing optical shutter 36 should be installed in a solar collector to avoid heating the building when it is absorbing. For example, a liquid crystal optical shutter has active ingredients of the same type as those chemicals that are known to be capable of creating digital displays in time pieces. For example, liquid crystals, sometimes in the form of droplets in a polymer matrix, are sandwiched between glass or plastic films, which are coated with a transparent conductor of electricity, such as an ultra-thin layer of indium/tin oxide that acts as an electrode. When a voltage is applied to the electrode, the liquid crystals align perpendicularly to the glass, and light passes through them. When the voltage is switched off, the liquid crystals scatter solar radiation, causing the optical shutter 36 to turn a translucent white.

[0042] Variations on the liquid crystal embodiment include an electrochromic glazing that has been likened to a transparent battery. This embodiment works by electronically altering the light-absorptive properties of a layer of electrochromic material (i.e., certain inorganic semiconductors called transition metal oxides, such as doped tungsten or vanadium oxides). These shutters also use two transparent electrodes. When a current is applied, ions from one layer and electrons from another migrate to yet a third layer -- the electrochromic material. The resulting chemical reaction causes the glazing to absorb light and become dark (typically blue colored). To reverse this effect, the polarity of the electrodes is reversed.

[0043] In addition to the liquid crystal and Cloud Gel optical shutters disclosed herein, other types of shutters, for example electrochromic shutters, are suitable. These materials act by electronically altering the light-absorptive properties of a layer of electrochromic material. Suitable electrochromic materials are certain inorganic semiconductors, for example, transition metal oxides, such as doped tungsten or vanadium oxides. Shutters utilizing these materials include two transparent electrodes. When a voltage is applied, ions from one layer and electrons from another layer migrate to

yet a third layer - the electrochromic material. The resulting chemical reaction causes the glazing to absorb light and turn dark (typically bluish). To reverse the effect, the polarity of the two electrodes is reversed. Some of the companies developing electrochromic technologies are PPG, Pittsburgh, PA; SAGE Corp., Valley Cottage, NY; the Solar Energy Research Institute, Golden, CO; and Lawrence Berkeley Laboratory, Berkeley, CA.

[0044] Another type of electochromic optical shutter is a suspended particle optical shutter. Suspended particle optical shutters resemble liquid-crystal technology in that the active ingredients, for example, polyiodine crystals, change orientation in response to an applied voltage. Until recently, developers were using needle-like crystals suspended in a dense fluid and sandwiched between two sheets of glass, both again coated with a transparent conductive material. When a voltage is applied, the needles align perpendicularly to the walls, allowing the light to pass through. When the electricity is switched off the particles scatter and absorb light; then the glazing looks dark blue. One developer, Research Frontiers, Inc., Woodbury, NY, is working on a process that encapsulates particle-laden drops of liquid in plastic film. A convection baffle can be added to the low emissivity coating of the solar collectors used herein.

[0045] When a shutter becomes absorbing in order to reject the heat of incoming solar radiation, the shutter itself heats up and must be insulated from the building's interior by the transparent insulation. Thus an absorbing type shutter should be located between the glazing and the transparent insulation as is shown in figure 4. If the optical shutter is the reflective type, it can be located on either side of the transparent insulation (see Figure 12). In the event that the heat storage element is also transparent, then a reflective optical shutter may be located on either side of the transparent thermal storage element. If the reflective optical shutter is thermochromic (like Cloud Gel, for example), it may be located inside the structure from the transparent insulation, so that it will turn reflective when the building and/or its thermal storage are too warm and will turn opaque when the building and/or its thermal storage are too cool, as shown in figures 3A and B and 6.

[0046] In another variation, Figure 7 illustrates an alternate embodiment of the transparent insulation layer 30, in which one or two low emissivity layers 32 are affixed to the interior surfaces of a glass-enclosed vacuum 43.

[0047] In yet another variation, Figure 8 illustrates an alternate embodiment of the transparent insulation layer 30, in which a layer of honeycomb material 44 is oriented with its openings 46 approximately perpendicular to the encasing layers of a transparent glazing material 26. In this embodiment optical shutters 36 are optionally-placed on top of or below the layers of honeycomb material 44.

[0048] Figure 9 shows the honeycomb material 44 with its openings 46 approximately perpendicular to the layer of transparent glazing material and roof exterior 24.

[0049] In yet another variation, Figure 10 shows an alternate embodiment of the honeycomb material 44 with its openings 46 oriented approximately perpendicular to the building's 20 floors 50.

[0050] In a further variation, Figure 11 shows an alternate embodiment of the transparent insulation layer, comprised of aerogel 52 which is adjacent to the layer of transparent glazing material 26. The aerogel 52 is a finely divided material with solid elements thinner than ¼ wavelength of solar radiation (100nm) but absorbing of thermal radiation.

[0051] Suitable transparent insulation components exemplified in Figures 7-11 are known in the art and they are exemplified by: honeycomb structures, disclosed by Volker Wittwer "Transparent Insulation Materials," OPTICAL MATERIALS TECHNOLOGY, p. 284, March 1990, International Society For Optical Engineering; honeycomb structures and low emissivity coatings disclosed in U.S. Patent Nos. 3,953,110, 4,085,999 and 4,389,452, all by D. Chahroudi; Vacuum disclosed by J.D. Garrison in "Evaluation of a Thermally Insulating Vacuum Window," 15th National Passive Solar Conference, p. 43, American Solar Energy Society, March 1990; and aerogels, disclosed by M. Mielke et al. in "Aerogels - a new class of material," presented at The 1st International Workshop on Transparent Insulation Materials for Passive Solar Energy Utilisation, p. 25, November 27-28, 1986, German section of International Solar Energy Society. All of the aforementioned patents and publications are incorporated herein by reference in their entirety.

[0052] Although the need for heat storage is substantially reduced with the use of the solar collectors used herein, it is not completely eliminated and heat storage helps to ensure sufficient heating capacity to provide heat to the building overnight. In Figure 12A, there is shown schematically a variety of relative locations of various necessary and optional layers which can be used to form a solar collector 22. This Figure is included to provide a basis for explaining hereinafter various alternative embodiments of the construction of the solar collector 22. In Figure 12A, a cross-section of a solar collector 22 includes a heat storage element 42; similar heat storage elements are shown in: Figure 13 (elements 50 and 56); Figure 14 (element 50); and Figure 2 (element 25).

[0053] As shown in Figure 12A, the location of the heat storage element 42 may be below and in proximate location (also referred to herein as "heat transfer relationship") to a part of the solar collector 22. By proximate location (also referred to herein as "heat transfer relationship") it is meant that the heat storage element 42 is positioned in such a relationship to the rest of the solar collector that the energy received by the solar collector is transferred to the heat storage element 42 by heat transfer mechanisms, as described hereinafter. For example, Figure 12A indicates several of the possibilities for the heat storage element 42 location, e.g., between and adjacent to the solar radiation absorbing material, whose location is alternatively indicated as 40A or 40B, and the optional interior finish 54 and optical shutter 36B or transparent insulation 30. Heat storage element 42 must be placed below the transparent insulation 30, as

shown in Figure 12A. If the heat storage element 42 is transparent, then a reflective thermochromic optical shutter 36 may be located on either side of the transparent heat storage element 42 as indicated by alternative locations 36C or 36D. If the reflective optical shutter 36 is thermochromic, it should be located inside the structure 20 (not shown) from the transparent insulation 30 so that the reflective optical shutter will become reflective when the structure 20 (not shown) and its heat storage element 42 are too warm, and the reflective optical shutter will turn transparent when the building 20 and/or its heat storage element 42 are too cool, as shown in Figures 3A, 3B and 6. A more complete description of various exemplary embodiments possible with the diagram of Figure 12A is included in Examples 14 and 15 of this application.

[0054] Figure 13 illustrates several additional variations on the placement of the heat storage element 42. This figure illustrates the design for a single family home which may provide fresh fruit, vegetables, flowers, water and air in addition to heat for a small increase in cost over the other embodiments of the invention. For example, the heat storage element 42 (not shown) may be (located in) the floor 50 below the roof 24, or in the space 60 between the floor 50 and the roof 24, or in objects such as plants 62 and soil (56) in the greenhouse 60 which are located in the top story or attic 64 of a building 20, within the insulating envelope 23 of the building 20. As shown in Fig. 13, the greenhouse 60 with shade provided by potted trees and rows of planters hanging just below the ceiling makes the top floor 64 free from glare. This space may then be used as a living room, dining room or kitchen. The soil 56 for the plants 62 provides thermal storage. The plants 62 freshen the air by removing pollution and replacing CO_2 with O_2. Water that has been used for washing and household chores is fed to the plants, where it ultimately transpires from the leaves. This distilled transpiration condensate may be collected from the inside surface of the solar collector 22 ceiling.

[0055] Alternatively, the heat storage element 42 can be located in objects already located for other purposes within the insulation envelope 23 of the building, by way of example, objects that are located in the building 20 for reasons other than heat storage. Thus, for example, a sheetrock or plasterboard wall or ceiling surfaces or a cement floor or furniture all store heat well, but are normally placed inside a building 20 without regard to their ability to store heat. The attic 64 shown in Figure 13 represents a solar still. A solar still is an apparatus which uses solar radiation to purify water through evaporation and condensation, and then collecting the condensate. In Figure 13, water content in the air, for example, humidity transpired through the leaves of plants, rises upwards towards the roof due to air currents and diffusion, where it is condensed on the glass surface. The condensation is then collected as purified water. The plants 62 perform the function of an evaporator 70 (not shown separately) and the interior surface 72 of the solar collector 22 performs the function of a condenser and collector of distilled water. Condensation flows along the interior surface of the solar collectors to a collection point and collection trough similar to trough 73 as shown in Fig. 18 at the lower edge 54 of the roof 24 (see Figures 13, 18 and 20).

[0056] Figure 14 is a schematic illustration of air flow through the building 20. As shown in Figure 14, heat transfer may be accomplished by means of air circulated by fans 76 through ducts 80. In Figure 14 for example the ceilings 50 serve as heat storage elements. Heated air is driven from the heat storage elements 24 and 26 by a fan 76 through a duct 80 to the remainder of the building's 20 interior. In winter, heat may be circulated from the attic or top floor 51 to the remainder of the building 20 in this way. The air circulation loop (59 A, B & C) is completed through ceiling/floor vents 58 (only one of which is shown, but several of such vents may be included) from the lower floors 59 to the attic 51. In the summer, the same fan 76 may be used to circulate outside air through the attic 51 by obtaining the air from the outside through vent holes (not shown) customarily provided in most roof buildings. During daytime, heat circulation dumps out the heat load caused by the small solar energy transmission of the solar collectors 22 in their opaque state. At night the fan 76 cools the whole building 20 and thermal storage elements 50 with night air. The pattern of air circulation is schematically illustrated in Figure 14 by arrows 59A, 59B and 59C.

[0057] Figure 15 illustrates an air-to-air heat exchanger 74 including separate fans 77A and 77B connected thereto which drive the air in circulation loops 82. The air-to-air heat exchanger 74 can be used to transmit heat retained in an upperlevel greenhouse (represented by the attic 51 and in Figure 13 by 60) to the lower level of a building within the insulation envelope 23 while preventing humidity from leaving the upper level to the building's 20 interior 24. The pattern of air circulation is also schematically illustrated in Figure 15 by arrows A, B and C.

[0058] Figure 16 shows an alternative embodiment wherein heat is stored in water. In Figure 16, for example, the roof 24 of the building 20 is equipped to retain water 84, and the heat retained by the water 84, derived from the solar collectors 22 is circulated to other portions of the building's 20 interior 83 by means of a pump 86 and a network of pipes, exemplified by pipe 90 which is connected to a series of heating elements throughout the building 20 interior. Suitable heating elements are, for example, radiators, such as a radiator 92. In this way the entire insulation envelope 23 is heated. The roof 24 retains water in any suitable manner. For example, the roof may be constructed of metal sheets with tubes soldered to them or of plastic extrusions with channels for water heat storage and circulation.

[0059] Figure 17 illustrates an embodiment wherein beat storage elements 42 are contained in the floor 50 below the solar collector roof 24, heat transfer to the remainder of the building's 20 interior 83 can occur by means of thermal radiation, schematically illustrated by an arrow A.

[0060] Figure 18 illustrates placement and operation of a solar still 66. Impure water 70 is evaporated on the attic floor

50 and condensed on the interior portion 72 of the solar collector 22. The resultant condensate, or distilled water, is then collected by troughs 73 located at the lower edge 54 of the ceiling 22 and (not shown) end walls. The impure water is, for example bad well water or wash water from clothes, dishes and bodies of humans. The floor 50 must be constructed in such a fashion that it is able to support a one inch or greater layer of water. The floor 50 is therefore made of, for example, a water proof plastic film on top of a level roof of conventional construction.

[0061] Figure 19 shows the operation of the air-to-air heat exchanger 74, in which fan 76 drives humid heated air and fan 78 drives relatively cooler air through a condenser apparatus which may be, for example, no different from a conventional heat exchanger wherein condensate drops accumulate and flow to a condensate outlet pipe 80. This figure is a detail of the heat exchanger in Figure 15 and is installed in the building in the same way. Heated moist air is produced for example by the attic 66 in Figure 18 or 64 in Figure 13. Cooler air comes from the building below the solar collector and water evaporator 68 in Figures 13 and 18.

[0062] Figure 20 illustrates the framing detail of the attachment of multiple solar collectors 22 to the rafter 100 of the roof (not shown) of a building (not shown); 73 are the channels for collection of distilled water. The solar collectors 22 are sealed by a rubber weather seal to a grid of rafters 100 made from wood, steel or aluminum.

[0063] The HETIOSSC used herein may include a layer of optical shutter, protective glazing, optional heat storing elements, optional solar absorbing material and transparent insulation; the transparent insulation may, for example, be made of low emissivity layers, or low emissivity layers with convection baffles, or low emissivity layers with a layer of vacuum, or honeycomb material or aerogel material. Several components of the HETIOSSC used herein are the subject of WO-A-9 216 702, entitled "Light Admitting Thermal Insulating Building," describing some configurations of glazing, transparent insulation optical shutter, and absorber components of the present invention. Briefly, HETIOSSC is a solar collector with layers of: transparent glazing forming the building's exterior surface; a transparent insulation with a thermal conductivity less than 1 • 6W/m^2/°K (0.3 BTU/ft/°F/hr.); an optical shutter which transmits three or more times as much solar radiation energy in its transparent state as in its opaque state; and optional layer of solar absorbing material; an optional layer of thermal storage material; and an optional layer of interior finish. A HETIOSSC replaces a roof or wall element in a building. In its transparent state, an HETIOSSC has a solar transmission (more precisely, hemispherical solar energy spectrum transmission) of greater than 30%. What is claimed in this application is not HETIOSSC or other solar collectors, but building design using such solar collectors.

[0064] The novel passive solar heated heating design strategy of the present invention wherein high performance transparent insulations are used to collect solar energy during cloudy weather is highly effective for solar heating. Thermal modeling indicates that this design strategy may result in 80-100% solar heating in Boston and 63-100% in Berlin, both cities with cold and very cloudy winters, depending on the particular building design. Because heat is collected during cloudy weather, only overnight thermal storage is needed and the backup heater can be smaller and less expensive. Also, because part or all of the roof is used as the collector and because solar performance is relatively insensitive to collector orientation (solar radiation comes from all directions during cloudy weather) aesthetic impact is minimal and thus, the architect or contractor has almost complete freedom of design. A transparent insulation and optical shutter can be combined into a roof with a cost comparable to average conventional roof construction. These HETIOSSC make possible a design strategy for passively heated buildings which performs well in northern climates and which is comparable in initial costs and ease of design and construction with a building heated entirely with fossil fuel.

[0065] With the advent of HETIOSSC technology, described in WO-A-9 216 702 an entirely different design strategy has become possible. The transparent insulation components of HETIOSSC can include low emissivity coatings, convection baffles, transparent capillary and honeycomb buildings, evacuated windows, aerogels, and multiple panes of anti-reflected plastic film or glass. (see Transparent Insulation Technology for Solar Energy Conversion; International Workshop at the Fraunhofer Institute; Freiburg, Germany; 1986, 1988, 1989, 1991; Transparent Insulation Materials, Volker Wittwer, Optical Materials Technology, P. 284, March, 1990, International Society for Optical Engineering; U.S. patents 3,953,10, applied for 1974; 4,085,999, applied for 1976; and 4,389,452 applied for January 18, 1978, all by Day Chahroudi; "Evaluation of a Thermally Insulating Vacuum Window," John D. Garrison, 15th National Passive Solar Conference, P. 43, American Solar Energy Society, March, 1990. Aerogels - A new class of Material, M. Mielke, Transparent Insulation Materials, P. 25, November, 1986, German section of International Solar energy Society.) These materials have insulating values equal to one to two inches of plastic foam, which is comparable (but not necessarily equal) to the insulating value of typical roof and wall construction. At the same time, these high performance transparent insulations transmit from 50% to 70% of incident solar energy.

[0066] The insulation value of these transparent insulation materials is high enough that the solar collector can be integrated into the building's construction without using a separate layer of opaque insulation to prevent nighttime heat losses. Thus, the HETIOSSC can be directly substituted for a complete roof or wall element, rather than being added externally. Since HETIOSSC may cost no more than an average roof or wall, the cost of installing solar space heating is greatly reduced.

[0067] Because this novel design strategy calls for collecting heat on cloudy days, the HETIOSSC surface points up at the clouds. Thus the roof, rather than the south wall, becomes the preferred location for solar collectors. An added

benefit of replacing roof rather than wall panels with solar collectors is minimal impact on building esthetics - a HETIOSSC solar heated building would differ in appearance from a conventional non solar building only in having its roof glazed. Because cloudy weather sunlight comes from straight above, orientation of the HETIOSSC heated building and its roof collector is not crucial, nor is the floor plan, allowing the architect almost complete freedom of design. Because sunlight is less intense during cloudy weather, a large collector area is called for, so more than half of the roof should consist of HETIOSSC, depending on local climate.

[0068] The convection baffle is added to the low emissivity coating as shown in Figures 3A, 3B and 3C. A suitable material for a convection baffle is a clear plastic film. The use of these films as a convection baffle can almost double the insulating value of the low emissivity coating and is available at a fraction of the cost of a second low emissivity coating. Convection baffles can be made of sunlight resistant polyethylene with excellent solar energy transmission properties of up to 92%. Their function is to inhibit convection currents within the air spaces of HETIOSSC without interfering with the operation of the low emissivity coated glass or plastic film. This polyethylene, unlike most plastics, is 90% transparent to long-wave infrared radiation between 3 and 40 microns wavelength, the kind of radiation that transfers heat. (If the baffles absorbed much IR, they would act to transfer thermal radiation despite the low emissivity coated layer and greatly diminish the low emissivity layers' effectiveness.) Unlike most polyethylenes, this one is extremely transparent to sunlight and can hold up under the sun's ultraviolet rays for 30 years. Convection baffles double the thermal resistance of a HETIOSSC over using low emissivity coatings alone, and they cost very little.

[0069] The insulating value of HETIOSSC can be comparable to conventional walls and roofs. Their expected lifespan can be up to 30 years. When production volumes become large, they may cost no more than an average wall or roof which captures no solar heat or illumination. If they are installed in the wrong place, they simply turn opaque and stay opaque, resulting in little excess heat gain or loss, or glare.

[0070] With one layer of low emissivity coating, two layers of convection baffle, and a layer of Cloud Gel (see figure 3A), the HETIOSSC has a thermal conductivity of .20 BTU/ft^2/°F/hr. (1.1 watt/sq meter °K) and solar transmission which varies between 70% and 7%, with most of this change occurring over a change of 3°F (about 2°C). The high degree of light transmission of this HETIOSSC configuration recommends it for greenhouse use. With two layers of low emissivity coating alternating with four layers of convection baffle, plus one layer of Cloud Gel (see Figures 3B and C), the thermal conductivity is 0.10 BTU/ft^2/°F/hr. (or 0-57 watt/sq meter °K), with solar transmission of 50% to 5%. The low thermal conductivity of these Weather Panels makes them suitable for collecting heat during cloudy weather.

[0071] The HETIOSSC may be surfaced with a glazing of either plastic film, low iron glass, fiber reinforced plastic, or plastic sheet in order to serve various market segments, including passive space heating, daylighting (skylights), greenhouses, and a transparent building enclosure which generates its own climate (see figure 2). This type of transparent insulation enclosure, as previously disclosed by Day Chahroudi, 14th U.S. Passive Solar Conference, Denver, U.S.A. (1989), incorporated herein by reference in its entirety had a thermal conductivity of greater than 1 • 6W/m^2/°K (0.30 BTU/ft^2/°F/hr), and therefore had lower thermal performance than the transparent insulation enclosure used herein. The building designs disclosed in that paper would not perform well in northern climates if they used the previously disclosed transparent insulation which was a low emissivity coating without convection baffles. Therefore, it is important that the solar collectors used in this invention use transparent insulation which has a thermal conductivity less than 1 • 6W/m^2/°K (.30 BTU/ft.^{2}/°F/hr).

[0072] As is shown in Figure 3C, any of these HETIOSSC configurations may have their indoor surface painted a dark color to match the building's exterior and to absorb solar radiation. This surface may then be covered with, for example, wallpaper or plaster for an interior finish. The shadow cast by the Weather Panel edges and the structural framing system shown in Figure 20 is only about 4%.

[0073] Although the design strategy based on using HETIOSSC to collect sufficient solar heat during cloudy weather greatly reduces the requirements for thermal storage of the solar beat which they collect, the need for thermal storage is not eliminated. However, only overnight storage is needed to heat the building until the next cloudy day. Overnight storage may be in the walls, ceilings and furniture already in the building, or a separate heat storage element may be used, as is shown in: Figure 2 (element 25); Figure 9 (element 50); Figure 10 (element 50); Figure 12A (element 42); Figure 13 (elements 50 and 56); Figure 14 (element 56); Figure 16 (element 50); Figure 17 (element 50); Figure 18 (element 70). Computer modeling has shown that the percentage of annual heating load supplied by solar heating increases rapidly as thermal storage increases up to the amount needed for overnight storage on the average day of the coldest month of the year in the climate where the building is located. However, the percentage of heating supplied by solar energy increases very slowly when the amount of thermal storage is increased beyond overnight storage because heat is supplied by the next day's cloudy weather, unlike the conventional sunny weather passive design strategy.

EXAMPLES 1 TO 13

COMPUTER MODELING BUILDING SOLAR PERFORMANCE

[0074] Thermal modeling results for 13 examples of computer modeling of building solar performance are summarized in the chart below. Boston and Seattle have some of the worst weather in the U.S. for passive heating. Tokyo, Paris and London have winter climates very similar to Boston and Seattle. These results are a bit optimistic; real buildings only closely approach the performance of their computer models, depending on the builder's skill. Because the non solar reference building is so well insulated, the percentages of supplementary heat indicated in the chart represent small absolute values of heat. These performance figures are much better than is achievable in these cloudy climates by the previous strategy of designing collectors for sunny winter weather and storing heat for cloudy days. Calpas3, developed by USDOE Lawrence Berkeley Laboratory, available from Berkeley Solar Group, Berkeley, CA was used to generate the percentage solar heating performances in the chart.

EXAMPLES 1-13

[0075]

PERCENTAGE SOLAR HEATING (Example Nos. In Parenthesis)			
Solar collecter	figs. 1 and 13 through 18 fig. 3B or C	fig. 2 fig. 3B	fig. 2 fig. 3A
Boston	80% (1)	100% (6)	97% (10)
Seattle	76% (2)	100% (7)	90% (11)
Munich	77% (3)	100% (8)	86% (12)
Berlin	63% (4)	100% (9)	86% (13)
super insulated	79% (5)		

[0076] The performance of the designs shown in Figures 1, 2, and 13 through 18 were modeled using the Calpas 3 program. [1/] Since this program does not model optical shutters, the HETIOSSC were assumed to always be at their maximum transmission and excess heat was vented. Since the buildings in Figures 1 and 13 through 18 have almost the same collector to wall area ratios, they are assumed to have almost the same solar performance. The following assumptions were used for the buildings in Figures 1 and 13 through 18: the roof is oriented with its ridge at 45° to the north-south axis to simulate a random orientation; thermal storage is in a two inch (5 centimeters) uninsulated concrete floor of the attic (see Figure 13, element 50, for example), except in Berlin, where it is six inches (15 centimeters) thick; wall conductivity is 0.05 BTU/ft^2/°F/hr. (.28 watts/sq meter/°hr.); windows are 10% of the floor area, and have a conductivity of 0.17 BTU/ft.^{2}/°F/hr. (1.0 watt/meter^2/°hr.); the foundation has a conductivity of 0.10 BTU/ft^2/°F/hr. (.19 watts/meter^2/°hr.); the infiltration rate is one air change every four hours for the apartment, and eight hours for the attic or greenhouse. The minimum temperature inside the apartment and the attic or greenhouse is 65°F (18°C) during the day, and 60°F (15°C) for seven hours during the night; the attic is the same temperature as its heat storage floor. The attic fan's rate is 5,000 cfm (10,000 cu meter/hr) for the building in Figure 1; for the building in Figure 2, the same assumptions as above were made when they applied, except the thermal storage is six inches (15 centimeters) of concrete; the building of Figures 1 and 13 though 18 can be "super-insulated" by reducing the infiltration from one quarter to one eighth air change per hour, and by increasing wall insulation from a conductivity of 0.05 BTU/ft^2/°F/hr. (.28 watts/sq meter °K). The percentage of solar heating was computed in relation to buildings which are identical to the above buildings except that the roof is opaque and has a conductivity of 0.05 BTU/ft^2/°F/hr. (.28 watts/sq meter/°K/hr.) and the windows do not use HETIOSSC, but only low emissivity coatings, and so have a conductivity of 0.33 BTU/ft^2/°F/hr. (1.9 watts/sq meter/°K/hr.)

[1] Calpas 3, developed by USDOE Lawrence Berkeley Laboratory, is available from Berkeley Solar Group, Berkeley, CA.

Description of Weather Data Used:

[0077] The CALPAS3 model uses hourly weather data for one entire year to simulate the building solar heating performance. There exist over 200 of these data sets for the US. These US data sets are called TMY (Typical Meteorological Year) data sets. While it is possible to model shorter periods, to get precise annual performance, something equivalent to a full year is required. Since a complete typical (or average) year in Europe was not easily available to us, we chose to use a method which should give accurate results: that of creating 12 short data sets each representing an average month for the location under consideration and similar means deviations. Each of these data sets was selected from the TMY data sets for the US, which had average weather characteristics closest to the location under consideration. For each month, a sequence of 2 to 5 days was selected from the TMY, which had average values of solar radiation and temperature closest to that of the average value of the location under consideration. The number of days depended on the mean deviation for that month. The simulation was then run for the short period, and the results were taken as representative for the months.

Description of the CALPAS3 Model Variables Used:

[0078]

TITLE: This is just a descriptor, not used in the calculations.
AZMSOUTH: This was set to 45°. It means the building is rotated 45° from the true north-south orientation.
Those following refer to the heated portion of the building, not the sunspace (the space between optical shutter and thermal absorber, such as the greenhouse or attic in Figure 13):
HOUSE; FLRAREA is the floor area of the heated space (square feet), VOL: volume of the heated space (cubic feet). These parameters are required by the program. When we were modeling a sunspace alone, as in Figure 2, we set these values to one.
ROOF: AREA is the roof area (square feet). This parameter is required by the program. Since we were modeling a configuration with the sunspace on top of the building, there was no roof. We set this value to one.
WALL: The following apply to any opaque vertical exterior surface of the heated building. NAME is a descriptor, not used in the calculations. AREA is the area of the surface (square feet). AZM is the azimuth (compass direction) of the normal to the surface (degrees, 0-360). UVAL is the thermal conductivity of the surface in BTU/ft^2/°F/hr.
GLASS: NGLZ is the number of glazings. The other parameters are defined the same as for preceding WALL.
INFIL: ACBASE: the number of air changes per hour in the heated space due to infiltration.
INTGAIN: INTGAIN are other sources of heat inside the heated space (kWh/day).
VENT: TYPE=NATURAL models natural ventilation with inlet and outlet at 10% of the glass area, height difference of 2 feet for stack effects, and uses non directional wind for wind effects.
TSTATSWNTR: THEAT is the heating setpoint for backup heat to come on.
THEATNIGHT is the thermostat set point for nighttime backup heat to come on.
TIMEDOWN is the time when the control setpoint switches from the daytime to the nighttime control point.
The following refer to the sunspace:
SUNSPACE: These definitions are the same as for the HOUSE above.
SSROOF: These definitions are the same as for the house ROOF above.
SSWALL: These definitions are the same as for the house WALL above.
SSMASSWALL: AREA: the area of the mass wall (or floor in our case), (square feet). THKNS the thickness of the mass wall (inches). MATERIAL the material of the mass wall (used to calculate the thermal mass and conductivity).
HTASS: heat transfer from the mass wall inside surface into the sunspace air (Btu per hour per square foot per degree Fahrenheit). HTAHS: heat transfer from the mass wall into the heated space air (Btu per hour per square foot per degree Fahrenheit). HOLGLS: heat transfer from the mass wall onto the exterior glazing for the mass wall (Btu per hour per square foot per degree Fahrenheit). HGTASS: heat transfer from the sunspace glazing into the sunspace air (Btu per hour per square foot per degree Fahrenheit).
SSMWGLASS: these refer to the SSMASSWALL glazing just preceding. AZM: (same as AZM for house GLASS). UGLASS: (same as UVAL for house GLASS). (0 means no thermal energy lost or gained.) XRFLCT: the fraction of solar radiation reflected from this glazing. (1 means nothing transmitted.)
SSGLASS: these refer to the sunspace glazing. (this statement and the following two are repeated for each glazing with different characteristics.) AREA: (same as the AREA for the house GLASS). AZM: (same as AZM for house GLASS.) UVAL: (same as UVAL for house GLASS.) NGLZ: (same as NGLZ for the house GLASS.) TILT: the inclination of the glass from the horizontal (degrees). XRFLCT: the fraction of the solar radiation reflected from this glazing.
SGDISTWNTR: SSAIR: the fraction of solar gain through the SSGLASS which goes into the sunspace air in the

winter. SSMWO: the fraction of the solar gain through the SSGLASS which goes into the mass wall in the winter.
SGDISTSMR: SSAIR: the fraction of solar gain through the SSGLASS which goes into the sunspace air in the summer. SSMWO: the fraction of the solar gain through the SSGLASS which goes into the mass wall in the summer.
SSTSTATSWNTR: THEAT: setpoint for backup heating of sunspace in winter. TVENT: setpoint for ventilation of sunspace in winter.
SSTSTATSSMR: THEAT: setpoint for backup heating of sunspace in summer. TVENT: setpoint for ventilation of sunspace in summer.
SSCOUPLING: VENT=FAN: specifies fan coupling between sunspace and house. CFMMAX: amount of coupling (fan size). KWMAX: energy from fan added to heated space.
END: defines end of parameter list.

TABLE

TYPICAL DATA INPUT FOR CALPAS 3

```
TITLE Apartment House/ WEATHER PANEL R-10 X=50k
AZMSOUTH 45
HOUSE      FLRAREA=6200   VOL=60670
ROOF AREA=1
WALL NAME=NORTH      AREA=1320 AZM=180   UVAL= .05
WALL NAME=SOUTH      AREA=1320 AZM=  0   UVAL= .05
WALL NAME=EAST       AREA= 672 AZM=-90   UVAL= .05
WALL NAME=EAST       AREA= 672 AZM= 90   UVAL= .05
WALL NAME=DOORS      AREA=  24 AZM=180   UVAL= .2
WALL NAMES=DOORS     AREA=  24 AZM=  0   UVAL= .2
WALL NAME=PERIMETER AREA=  80 AZM=-90   UVAL= .05
WALL NAME=PERIMETER AREA= 160 AZM=  0   UVAL= .05
WALL NAME=PERIMETER AREA=  80 AZM= 90   UVAL= .05
WALL NAME=PERIMETER AREA= 160 AZM=180   UVAL= .05
GLASS  NAME=SOUTH    AREA= 200 AZM=  0   NGLZ=2     UVAL=.167
GLASS  NAME=NORTH    AREA= 200 AZM=180   NGLZ=2     UVAL=.167
GLASS  NAME=EAST     AREA= 100 AZM=-90   NGLZ=2     UVAL=.167
GLASS  NAME=WEST     AREA= 100 AZM= 90   NGLZ=2     UVAL=.167
INFIL      ACBASE=0.25
INTGAIN    INTGAIN=0
VENT TYPE=NATURAL
TSTATSWNTR      THEAT=65  THEATNIGHT=60  TIMEDOWN=22
SUNSPACE  FLRAREA=3100    VOL=15190
SSROOF     AREA= 130 TILT=30    UVAL= .1
SSWALL     NAME-EAST AREA= 193 AZM=-90   UVAL= .05
SSWALL     NAME-WEST AREA= 193 AZM= 90   UVAL= .05
SSMASSWALL      AREA=3100 THKNS=1   MATERIAL=WATER HTASS=0 &
     HTAHS=0.2 HOGLS=0   HOTASS=4  HGTASS=0
SSMWGLASS AZM=0      UGLASS=0  XRFLCT=1
SSGLASS    AREA=1790 AZM=  0    TILT=30   NGLZ=1    UVAL= .1
&
     XRFLCT=.47
SGDISTWNTR  SSAIR=0 SSMWO=1
SGDISTSMR SSAIR=0   SSMWO=1
SSGLASS    AREA=1790 AZM=180    TILT=30   NGLZ=1    UVAL= .1
&
```

```
        XRFLCT=.47
    SGDISTWNTR   SSAIR=0 SSMWO=1
    SGDISTSMR SSAIR=0    SSMWO=1
    SSINFIL    ACBASE=0.125
    SSTSTATSWNTR     THEAT=60    TVENT=100
    SSTSTATSSMR      THEAT=60    TVENT=100
    SSCOUPLING       VENT=FAN    CFMMAX=5000      KWMAX=0
    ;PRINTDAILY      FIRSTDAY=JAN-1  LASTDAY=JAN-31
    ;PRINTHOURLY     FIRSTDAY=JAN=2  LASTDAY=JAY-7
    END
```

[0079] To design an appropriate solar collector the following general and specific design criteria (or rules) need to be followed. First, the general rules which must be followed are:

1. that only one layer each of the outer glazing, the shutter, the transparent insulation, the absorber, the heat storage element and the interior finish is required; and
2. an optional part of the solar collector (but needed in either the collector or the building) is the absorber, heat storage element, and the interior finish.

The specific rules to be complied with are as follows:

3. the outer glazing is on the outside;
4. if the heat storage is transparent, it may be inside or outside the absorber and the shutter;
5. the absorbing shutter is between the outside glazing and transparent insulation;
6. the thermochromic reflective shutter is both inside from the transparent insulation and outside from the absorber;
7. the thermochromic reflective shutter is outside the absorber;
8. the thermal storage is inside the transparent insulation and the shutter;
9. the heat storage element is inside the glazing and transparent insulation;
10. if the heat storage element is not transparent, then the heat storage element is inside the shutter and the absorber;
11. the transparent insulation is inside the glazing;
12. the interior finish is on the inside; and
13. the interior finish may be transparent if all preceding layers are transparent.

[0080] The application of these rules in conjunction with a reference to Figure 12B, results in specific embodiments for particular applications as illustrated in the following examples.

EXAMPLE 14

[0081]

Application Of Design Criteria To Form A Collection Having An Absorbing Shutter	
Structure Layers*	
A	1, 2, 3
B	1, 2, 3, 5
C	1, 2, 3, 5, 7
D	1, 2, 3, 7, 9
E	1, 2, 3, 5, 7, 10
F	1, 2, 3, 5, 10

* By reference to Figure 12B - Layer Numbers

EXAMPLE 15

[0082]

Application Of Design Criteria To Form A Collection Having Reflective Thermochromic Shutter	
Structure Layers*	
A	1, 3, 4
B	1, 3, 7, 8
C	1, 3, 7, 8, 9
D	1, 3, 7, 8, 9, 10
E	1, 3, 4, 5
F	1, 3, 4, 5, 10
G	1, 3, 4, 5, 7
H	1, 3, 4, 5, 7, 9
I	1, 3, 4, 5, 7, 9, 10
J	1, 3, 4, 6, 7, 8
K	1, 3, 4, 6, 7, 8, 10

*By reference to Figure 12B - Layer Numbers.

DEFINITIONS

[0083] For the purpose of this application, the terms used in the application are defined below:

[0084] A "high efficiency transparent insulation optical shutter solar collector (HETIOSSC)" is a solar collector with

layers of: transparent glazing forming the building's exterior surface; a transparent insulation with a thermal conductivity less than 1 • 6W/m²/°K (0.3 BTU/sq. ft./°F/hr.); an optical shutter which transmits three or more times as much solar radiation energy in its transparent state as in its opaque state; an optional layer of solar absorbing material; an optional layer of thermal storage material; and an optional layer of interior finish. A HETIOSSC replaces a roof or wall element in a building. In its transparent state, an HETIOSSC has a solar transmission (more precisely, hemispherical solar energy spectrum transmission) of greater than 30%.

[0085] A "transparent glazing" is a material which transmits solar radiation, such as glass, plastic sheet or film or translucent fiberglass reinforced plastic, and which protects the HETIOSSC from the weather.

[0086] A "transparent insulation" is a material which transmits solar radiation well but does not transmit heat well.

[0087] An "optical shutter" is a material or device with a controlled reversibly variable transmission of solar radiation. Its transmission may be controlled by temperature, electrical current of voltage, or mechanical action, for example. It blocks solar radiation either by reflecting or absorbing it.

[0088] A "low emissivity layer" is a material which emits less than 25% of room temperature thermal radiation in the wavelength range of 3 to 40 microns. It may be transparent and composed, for example, of a thin silver layer which is antireflected by two dielectric layers on each side, or of a layer of indium/tin oxide. It may be absorbing of solar radiation and composed, for example, of a layer of nickel suboxide on top of a layer of aluminum.

[0089] A "convection baffle" is a layer of material, such as a 0.025 mm thick polyethylene film, which absorbs less than 25% of thermal radiation between 3 and 40 microns wavelength.

[0090] "Specular transmission" is transmission without scattering; that is reflection where the radiation does not change its direction of travel.

[0091] "Specular reflection" is reflection without scattering; that is reflection where the radiation's direction of travel has equal angles of incidence and reflection to the surface in question, as with a mirror.

[0092] "Located for other purposes" means that the objects in question would be there anyhow, for reasons other than heat storage. Thus, for example, a sheetrock or plasterboard wall or ceiling surface, or a cement floor, or furniture all store heat well, but are normally placed inside a building without regard to their ability to store heat.

[0093] "Within the insulation envelope of a building" means anything interior to or contained within the opaque and transparent insulation of a building and the ground it is built on. Thus, for example, a brick wall forming the outside surface finish of a building would not be included within the insulation envelope of a building, nor would an exterior transparent glazing of a skylight.

[0094] An "interior finish" is, for example, a layer of wallpaper, plaster, or wood which gives the interior of a building a pleasing appearance, and/or is easy to clean.

[0095] A "solar still" is a device which uses solar radiation to purify water by evaporating it and then condensing it and collecting the condensate.

[0096] Of course, it should be understood that a wide range of changes and modifications can be made to the preferred embodiments described above.

Claims

1. A solar heated building having a solar collector (22), wherein

    more than half of the solar collector area is provided by a roof collector forming part of the roof of the building (20), the solar collector (22) having a maximum solar energy admittance of 30% or greater, and in that:
    the roof collector is formed from at least one panel comprising:
    a layer of transparent glazing (26);
    a layer of transparent insulation (30) with a thermal conductivity of less than 1 • 6W/m²/°K (0.3 BTU/sq. ft./°F/hr);
    a layer of optical shutter (36) located on one side of said transparent insulation (30), the optical shutter (36) having a maximum solar transmission three or more times greater in its transmissive state than in its opaque state; and
    a layer of solar radiation absorbing material (40) with an adsorption of the solar energy spectrum of 70% or greater;
    the building comprising further
    one or more heat storage elements (42) which store at least 70% as much heat as is necessary to heat the building overnight on the average day of the coldest month of the year where the building is located.

2. A building as in claim 1, wherein said optical shutter (36) becomes substantially opaque primarily by reflecting solar radiation; and is interposed between said transparent insulation (30) and said absorbing layer.

3. A building as in claim 1, wherein said optical shutter (36) becomes substantially opaque primarily by absorbing solar radiation; and is interposed between said transparent glazing (26) and said transparent insulation (30).

4. A building as in claim 1, wherein said optical shutter (36) becomes substantially opaque to solar radiation above a first predetermined temperature.

5. A building as in claim 1, where said optical shutter (36) becomes substantially opaque to solar radiation in response to a first applied voltage or current and which becomes substantially transparent to solar radiation in response to a second applied voltage or current of opposite polarity to that of the first.

6. A building as in claim 1, wherein said transparent insulation (30) includes one or more low emissivity layers (32).

7. A building as in claim 1, wherein said transparent insulation (30) includes one or more low emissivity layers (32) and one or more convection baffles (34) which are substantially transparent to both solar and thermal radiation.

8. A building as in claim 1, wherein said transparent insulation (30) includes one or more low emissivity layer (32) and one or more layers of vacuum in between or adjacent to said low emissivity layers.

9. A building as in claim 1, wherein said transparent insulation (30) includes one or more layers of honeycomb material which is:

oriented with its openings approximately perpendicular to the surface of said building's roof or floors;
substantially non-absorbing of solar radiation;
substantially specular in its transmission and reflection of solar radiation;
substantially absorbing of thermal radiation.

10. A building as in claim 1, wherein said transparent insulation (30) is made from one or more layers of aerogel.

11. A building as in claim 1, wherein a layer of interior finish (54) is below and in proximity to said absorbing material.

12. A building as in claim 11, wherein a layer of interior finish (54) is below and in proximity to said heat storage element (42).

13. A building as in claim 1, wherein part of said heat storage elements is a layer below and in proximity to said layers of transparent insulation (30) and optical shutter (36).

14. A building as in claim 13, wherein part of said heat storage elements is water.

15. A building as in claim 13, wherein part of said heat storage elements is a phase change material.

16. A building as in claim 1, wherein part of said heat storage elements is contained in the floor (50) below said roof.

17. A building as in claim 1, where in part of said heat storage elements is the interior walls, ceilings, floors and other objects already located for other purposes within the insulation envelope of said building.

18. A building as in claim 17, wherein part of said heat storage elements is provided by objects already located for other purposes between said roof (22) and the floor (50) below said roof.

19. A building as in claim 1, wherein heat is transported from part of said heat storage elements to part of the interior of the building by means of air circulated by fans (76) through ducts (80).

20. A building as in claim 19, wherein, for the purpose of not transporting humidity along with said transported heat:

an air to air heat exchanger (74) is interposed between said heat storage element and part of said building's interior;
separate fans (77A, 77B) drive the air circulation loops on either side of said heat exchanger (74).

21. A building as in claim 1, wherein heat is transported from said heat storage elements to parts of said building's inte-

rior by means of water circulated by pumps (86) through pipes (90, 92).

22. A building as in claim 1, wherein heat is transported from said beat storage elements to parts of said building's interior by means of thermal radiation.

23. A building as in claim 1, wherein the top storey or attic of said building is a greenhouse.

24. A building as in claim 1, including solar still comprising:

an evaporator of impure water interior to said building from said solar collector;
a condenser and collector of distilled water comprised of:
part of the interior surface of said solar collector;
and/or an air to air heat exchanger.

25. A building as in claim 24, where said evaporator includes plants in a greenhouse in the top storey or attic of said building.

26. A building as claimed in any preceding claim, wherein the roof is inclined at an angle of 30°, so that snow collected on the roof can slide off the roof.

Patentansprüche

1. Gebäude mit Solarheizung mit einem Sonnenwärme-Kollektor (22), wobei

mehr als die Hälfte der Fläche des Sonnenwärme-Kollektors gestellt wird durch einen Dach-Kollektor, der einen Teil des Dachs des Gebäudes (20) bildet, der Sonnenwärme-Kollektor (22) eine maximale Sonnenenergie-Admittanz von 30% oder mehr hat, und wobei
der Dach-Kollektor gebildet ist aus mindestens einer Platte, umfassend:
eine Schicht Klarsicht-Verglasung (26), eine Schicht lichtdurchlässiger Isolierung (30) mit einer Wärmeleitfähigkeit von weniger als 1 • 6W/m^2/°K (0.3 BTU/Quadratfuss/°F/Std.),
eine Schicht Sichtblende (36), angeordnet auf einer Seite der lichtdurchlässigen Isolierung (30), wobei die Sichtblende (36) eine maximale Sonnendurchlässigkeit hat, die in ihrem Zustand des Durchlassens von Strahlen drei- oder mehrfach größer ist als in ihrem lichtundurchlässigen Zustand, und
eine Schicht Sonnenstrahlen-absorbierendes Material (40) mit einer Adsorption des Sonnenenergiespektrums von 70% oder mehr,
wobei das Gebäude ferner umfasst:
ein oder mehrere Wärmespeicherelemente (42), die mindestens 70% der erforderlichen Wärme speichern, so dass das Gebäude über Nacht beheizbar ist an einem durchschnittlichen Tag im kältesten Monat des Jahres am Ort wo das Gebäude steht.

2. Gebäude nach Anspruch 1, wobei die Sichtblende (36) im wesentlichen lichtundurchlässig wird, in erster Linie durch Reflektieren der Sonnenstrahlung, und angeordnet ist zwischen der lichtdurchlässigen Isolierung (30) und der Adsorptionsschicht.

3. Gebäude nach Anspruch 1, wobei die Sichtblende (36) im wesentlichen lichtundurchlässig wird, in erster Linie durch Absorbieren der Sonnenstrahlung, und angebracht ist zwischen der Klarsicht-Verglasung (26) und der lichtdurchlässigen Isolierung (30).

4. Gebäude nach Anspruch 1, wobei die Sichtblende (36) im wesentlichen für Sonnenstrahlung undurchlässig wird über einer ersten vorbestimmten Temperatur.

5. Gebäude nach Anspruch 1, wobei die Sichtblende (36) im wesentlichen für Sonnenstrahlung undurchlässig wird als Reaktion auf eine erste angelegte Spannung oder einen Strom, und die im wesentlichen durchlässig wird für Sonnenstrahlung als Antwort auf eine zweite angelegte Spannung oder einen Strom mit einer zur ersten entgegengesetzten Polarität.

6. Gebäude nach Anspruch 1, wobei die lichtdurchlässige Isolierung (30) ein oder mehrere Niederemissions-Schichten (32) umfasst.

7. Gebäude nach Anspruch 1, wobei die lichtdurchlässige Isolierung (30) ein oder mehrere Niederemissions-Schichten (32) umfasst und ein oder mehrere Konvektions-Ablenkscheiben (34), die im wesentlichen durchlässig sind für sowohl Sonnen- als auch Wärmestrahlung.

8. Gebäude nach Anspruch 1, wobei die lichtdurchlässige Isolierung (30) ein oder mehrere Niederemissions-Schichten (32) enthält und ein oder mehrere Vakuum-Schichten zwischen oder neben den Niederemissions-Schichten.

9. Gebäude nach Anspruch 1, wobei die lichtdurchlässige Isolierung (30) ein oder mehrere Schichten Wabenmaterial enhält, welches ist:

   ausgerichtet mit seinen Öffnungen etwa senkrecht zur Oberfläche des Gebäudedachs oder der -böden,
   im wesentlichen nicht-absorbierend für Sonnenstrahlen,
   im wesentlichen spiegelartig in seiner Durchlässigkeit und Reflexion von Sonnenstrahlen,
   im wesentlichen absorbierend für Wärmestrahlung.

10. Gebäude nach Anspruch 1, wobei die lichtdurchlässige Isolierung (30) aus ein oder mehreren Schichten Aerogel besteht.

11. Gebäude nach Anspruch 1, wobei eine Schicht Innenputz (54) unter und nebst dem Absorbtionsmaterial ist.

12. Gebäude nach Anspruch 11, wobei eine Schicht Innenputz (54) unter und nebst dem Wärmespeicherelement (42) ist.

13. Gebäude nach Anspruch 1, wobei ein Teil der Wärmespeicherelemente eine Schicht ist unter und nebst der Schichten aus lichtdurchlässiger Isolierung (30) und Sichtblende (36).

14. Gebäude nach Anspruch 13, wobei ein Teil der Wärmespeicherelemente Wasser ist.

15. Gebäude nach Anspruch 13, wobei Teil der Wärmespeicherelemente ein Material für Phasenumwandlung ist.

16. Gebäude nach Anspruch 1, wobei ein Teil der Wärmespeicherelemente enthalten ist in dem Boden (50) unter dem Dach.

17. Gebäude nach Anspruch 1, wobei ein Teil der Wärmespeicherelemente die Innenwände, Decken, Böden und andere Gegenstände sind, die bereits für andere Zwecke in dem Isoliermantel des Gebäudes angeordnet sind.

18. Gebäude nach Anspruch 17, wobei ein Teil der Wärmespeicherelemente durch Gegenstände bereitgestellt wird, die bereits für andere Zwecke zwischen dem Dach (22) und dem Boden (50) unter dem Dach angeordnet sind.

19. Gebäude nach Anspruch 1, wobei die Wärme aus einem Teil der Wärmespeicherelemente in einen Teil des Gebäudeinnenren transportiert wird mittels Luft, die von Ventilatoren (76) durch ein Röhensystem (80) zirkuliert wird.

20. Gebäude nach Anspruch 19, wobei, damit keine Feuchtigkeit mit der transportierten Wärme mitgetragen wird:

   ein Luft-zu-Luft-Wärmetauscher (74) zwischen dem Wärmespeicherelement und einem Teil des Gebäudeinneren angebracht ist;
   getrennte Ventilatoren (77A, 77B) die Luftzirkulationsschleifen auf beiden Seiten des Wärmetauschers (74) antreiben.

21. Gebäude nach Anspruch 1, wobei Wärme aus den Wärmespeicherelementen zu Teilen des Gebäudeinneren transportiert wird mittels Wasser, das von Pumpen (86) durch Leitungen (90, 92) zirkuliert wird.

22. Gebäude nach Anspruch 1, wobei Wärme von den Wärmespeicherelementen zu Teilen des Gebäudeinneren transportiert wird durch Wärmestrahlung.

23. Gebäude nach Anspruch 1, wobei das obere Stockwerk oder der Dachboden des Gebäudes ein Gewächshaus ist.

24. Gebäude nach Anspruch 1, einschließlich solarer Destillierapparat, ferner umfassend:

einen Verdampfer für Schmutzwasser im Inneren des Gebäudes aus dem Sonnenwärme-Kollektor,
einen Kondensor und Kollektor für destilliertes Wasser, bestehend aus:
einem Teil der Innenfläche des Sonnenwärme-Kollektors, und/oder
einem Luft-zu-Luft-Wärmetauscher.

25. Gebäude nach Anspruch 24, wobei der Verdampfer Pflanzen in einem Gewächshaus umfasst im Obergeschoss oder Dachgeschoss des Gebäudes.

26. Gebäude nach einem der vorstehenden Ansprüche, wobei das Dach schräg ist in einem Winkel von 30°, so dass Schnee, der sich auf dem Dach angesammelt hat, vom Dach rutschen kann.

Revendications

1. Un bâtiment à chauffage solaire présentant un collecteur solaire (22), dans lequel

plus de la moitié de la surface de collecteur solaire est assurée par un collecteur de toit faisant partie du toit du bâtiment (20), le collecteur solaire (22) présentant une admitance solaire maximum de 30% ou davantage, et en ce que :

le collecteur de toit est formé à partir d'au moins un panneau comprenant:

une couche de vitrage transparent (26);

une couche d'isolant transparent (30) présentant une conductivité thermique inférieure à 1,6W/m^2/°K (0,3 BTU/pied carré/°F/heure);

une couche d'obturateur optique (36) placée sur un côté dudit isolant transparent (30), l'obturateur optique (36) présentant une transmission solaire maximum trois fois supérieure ou davantage dans son état de transmission que dans son état opaque ; et

une couche de matière (40) d'absorption du rayonnement solaire présentant une adsorption du spectre d'énergie solaire de 70% ou davantage ;
le bâtiment comprenant en outre

un ou plusieurs éléments de stockage de chaleur (42) qui stocke au moins 70% de la chaleur nécessaire pour chauffer le bâtiment, la nuit, pendant le jour moyen du mois le plus froid de l'année où le bâtiment est placé.

2. Un bâtiment comme à la revendication 1, dans lequel ledit obturateur optique (36) devient sensiblement opaque principalement par réflexion du rayonnement solaire ; et est interposé entre ledit isolant transparent (30) et ladite couche absorbante.

3. Un bâtiment comme à la revendication 1, dans lequel ledit obturateur optique (36) devient sensiblement opaque principalement par absorption du rayonnement solaire ; et est interposé entre ledit vitrage transparent (26) et ledit isolant transparent (30).

4. Un bâtiment comme à la revendication 1, dans lequel ledit obturateur optique (36) devient sensiblement opaque au rayonnement solaire au-dessus d'une première température prédéterminée.

5. Un bâtiment comme à la revendication 5, où ledit obturateur optique (36) devient sensiblement opaque au rayonnement solaire en réponse à l'application d'une première tension ou d'un premier courant et qui devient sensiblement transparent au rayonnement solaire en réponse à l'application d'une seconde tension ou d'un second courant de polarité opposée à celle de la première.

6. Un bâtiment comme à la revendication 1, dans lequel ledit isolant transparent (30) comprend une ou plusieurs couches de faible émissivité (32).

7. Un bâtiment comme à la revendication 1, dans lequel ledit isolant transparent (30) comprend une ou plusieurs couches de faible émissivité (32) et un ou plusieurs déflecteurs de convection (34) qui sont sensiblement transparents aux rayonnements tant solaire que thermique.

8. Un bâtiment comme à la revendication 1, dans lequel ledit isolant transparent (30) comprend une ou plusieurs couches de faible émissivité (32) et une ou plusieurs couches de vide entre lesdites couches de faible émissivité ou adjacentes à celle-ci.

9. Un bâtiment comme à la revendication 1, dans lequel ledit isolant transparent (30) comprend une ou plusieurs couches de matière en nid d'abeilles qui est :

orientée avec ces ouvertures approximativement perpendiculaires à la surface du toit ou des planchers dudit bâtiment ;

sensiblement non absorbant du rayonnement solaire ;

sensiblement spéculaire dans sa transmission et sa réflexion du rayonnement solaire ;

sensiblement absorbant du rayonnement thermique.

10. Un bâtiment comme à la revendication 1, dans lequel ledit isolant transparent (30) est réalisé à partir d'une ou de plusieurs couches d'aérogel.

11. Un bâtiment comme à la revendication 1, dans lequel une couche de finition intérieure (54) se trouve en dessous et à proximité de ladite matière absorbante.

12. Un bâtiment comme à la revendication 11, dans lequel une couche de finition intérieure (54) se trouve en dessous et à proximité dudit élément de stockage de chaleur (42).

13. Un bâtiment comme à la revendication 1, dans lequel une partie desdits éléments de stockage de chaleur est constituée par une couche en dessous et à proximité desdites couches d'isolant transparent (30) et d'obturateur thermique (36).

14. Un bâtiment comme à la revendication 13, dans lequel une partie desdits éléments de stockage de chaleur est constituée par de l'eau.

15. Un bâtiment comme à la revendication 13, dans lequel une partie desdits éléments de stockage de chaleur est constitué par une matière à changement de phase.

16. Un bâtiment comme à la revendication 1, dans lequel une partie desdits éléments de stockage de chaleur est contenu dans le plancher (50) en dessous dudit toit (1).

17. Un bâtiment comme à la revendication 1, dans lequel une partie desdits éléments de stockage de chaleur est constituée par les parois intérieures, les plafonds, les planchers et autres objets déjà placés pour d'autres buts à l'intérieur de l'enveloppe d'isolation dudit bâtiment.

18. Un bâtiment comme à la revendication 17, dans lequel une partie desdits éléments de stockage de chaleur est assurée par des objets déjà placés pour d'autres buts entre ledit toit (22) et le plancher (50) en dessous dudit toit.

19. Un bâtiment comme à la revendication 1, dans lequel la chaleur est transportée d'une partie desdits éléments de stockage de chaleur vers une partie de l'intérieur du bâtiment au moyen d'air amené à circuler par des ventilateurs (76) à travers des conduits (80).

20. Un bâtiment comme à la revendication 19, dans lequel, dans le but de ne pas transporter de l'humidité en même temps que ladite chaleur transportée :

un échangeur de chaleur air à air (74) est interposé entre ledit élément de stockage de chaleur et une partie de l'intérieur dudit bâtiment;

des ventilateurs séparés (74A, 74B) entraînent les boucles de circulation d'air de chaque côté dudit échangeur de chaleur (74).

21. Un bâtiment comme à la revendication 1, dans lequel de la chaleur est transportée depuis lesdits éléments de stockage de chaleur vers des parties de l'intérieur dudit bâtiment au moyen d'eau amenée à circuler par des pompes (86) à travers des canalisations (90, 92).

22. Un bâtiment comme à la revendication 1, dans lequel de la chaleur est transportée depuis lesdits éléments de stockage de chaleur vers des parties de l'intérieur dudit bâtiment au moyen de rayonnements thermiques.

23. Un bâtiment comme à la revendication 1, dans lequel l'étage supérieur ou attique dudit bâtiment est constitué par une serre.

24. Un bâtiment comme à la revendication 1, incluant un alambic solaire comprenant :

un évaporateur d'eau impure intérieure audit bâtiment en provenance dudit collecteur solaire ;

un condensateur et un collecteur d'eau distillée se composant de :

une partie de la surface intérieure dudit collecteur solaire ;

et/ou un échangeur de chaleur air à air.

25. Un bâtiment comme à la revendication 24, où ledit évaporateur comprend des plantes dans une serre à l'étage supérieur ou attique dudit bâtiment.

26. Un bâtiment comme revendiqué dans une revendication précédente quelconque, dans lequel le toit est incliné selon un angle de 30°, de sorte que la neige recueillie sur le toit peut glisser du toit.

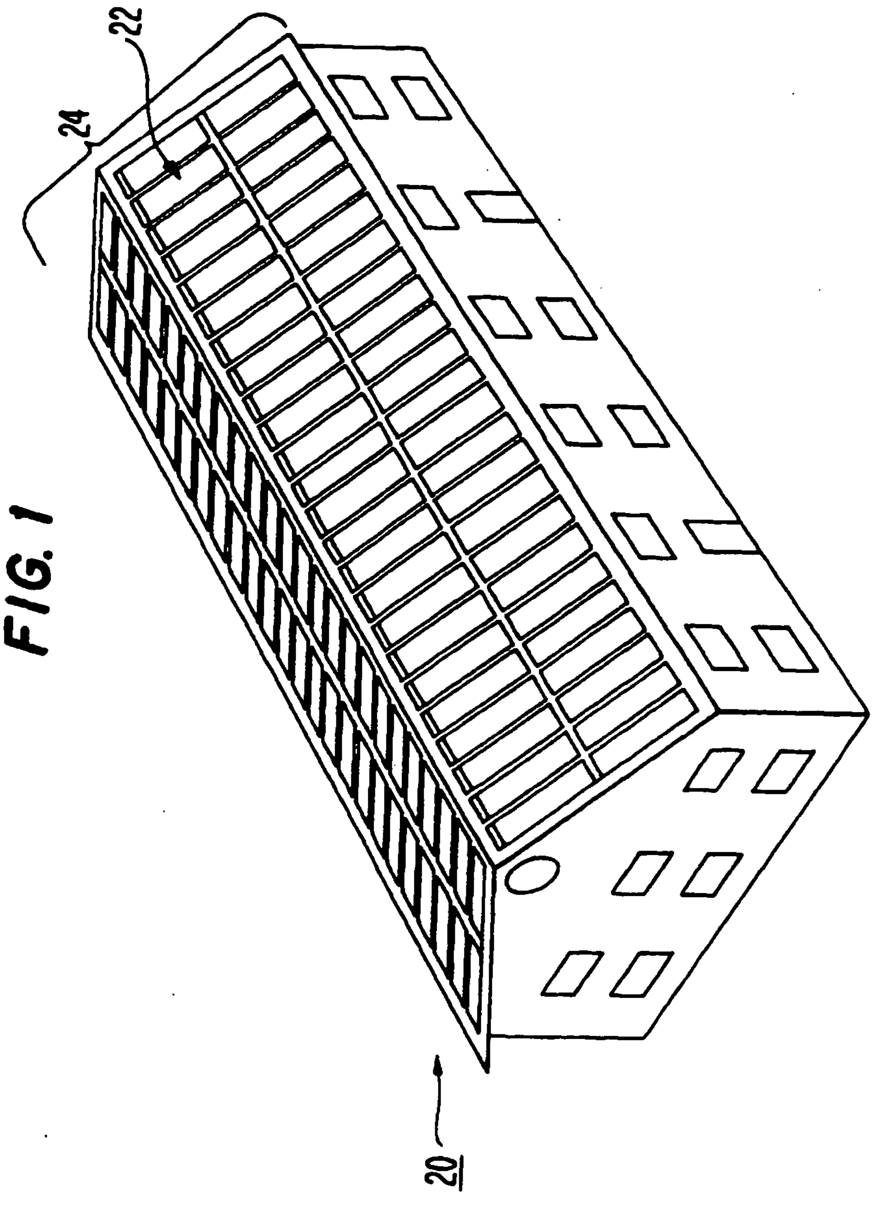


FIG. 1

FIG. 2

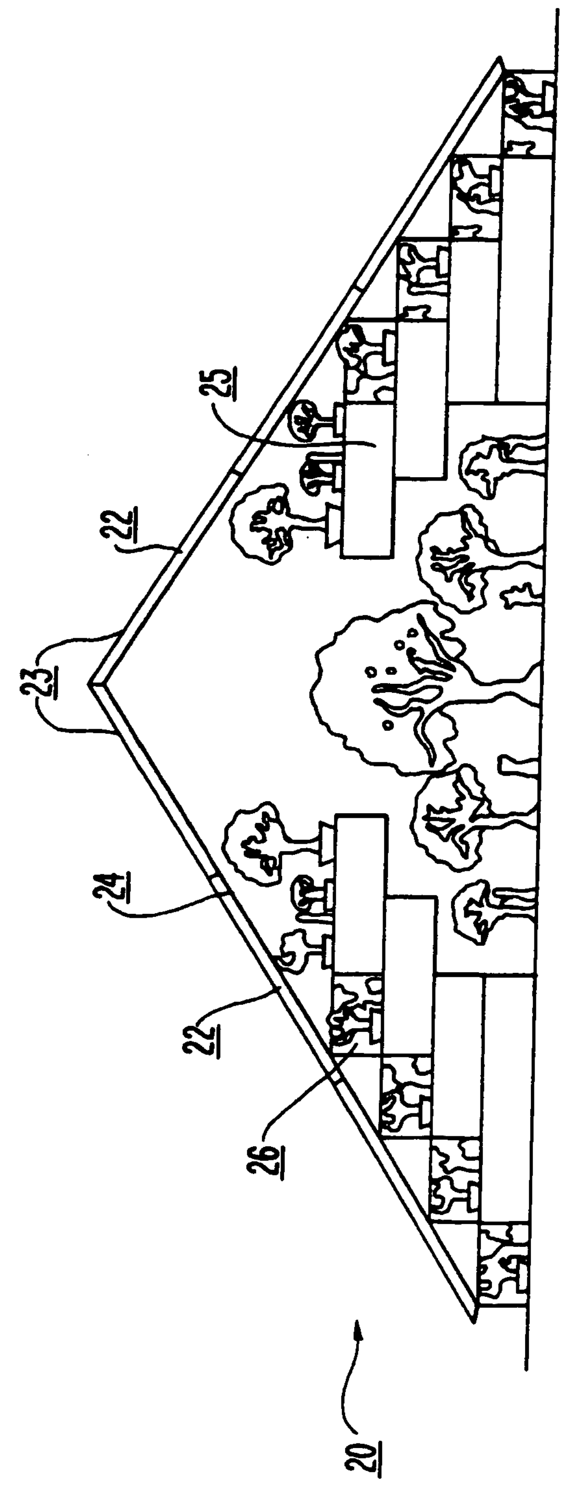


FIG. 3a

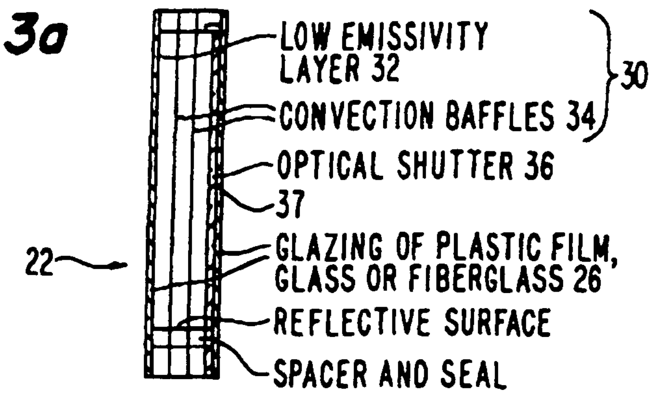


FIG. 3b

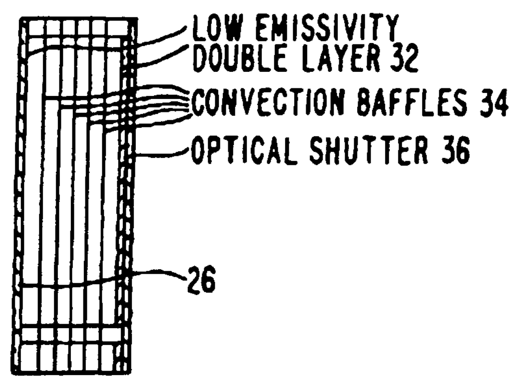


FIG. 3c

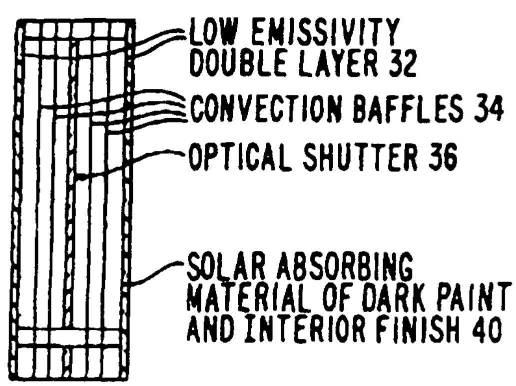


FIG. 3d

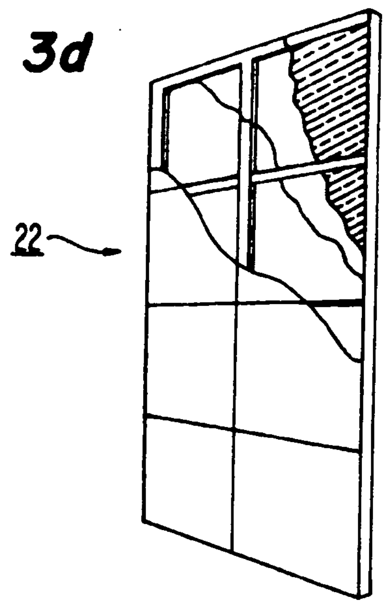


FIG. 4

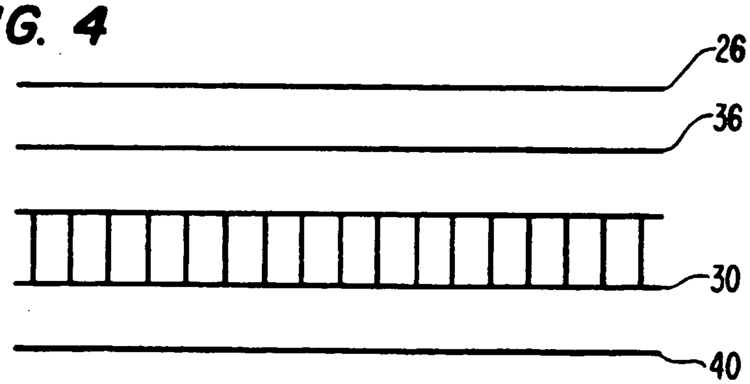


FIG. 5

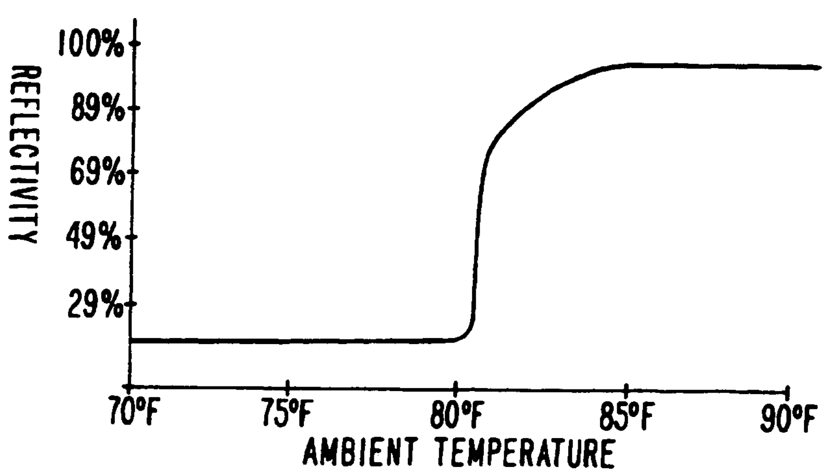


FIG. 6

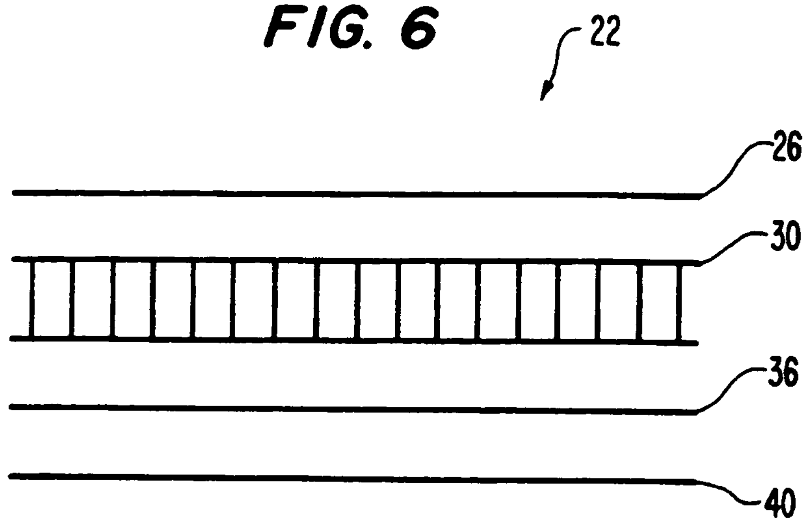


FIG. 7

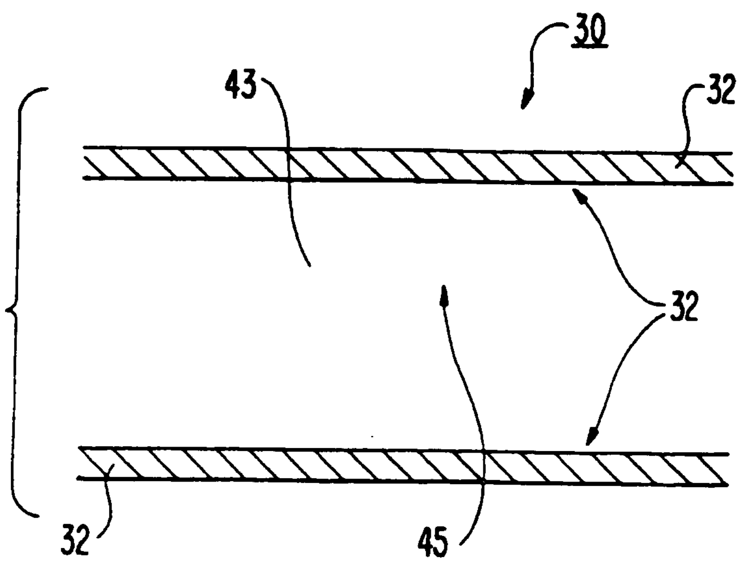


FIG. 8

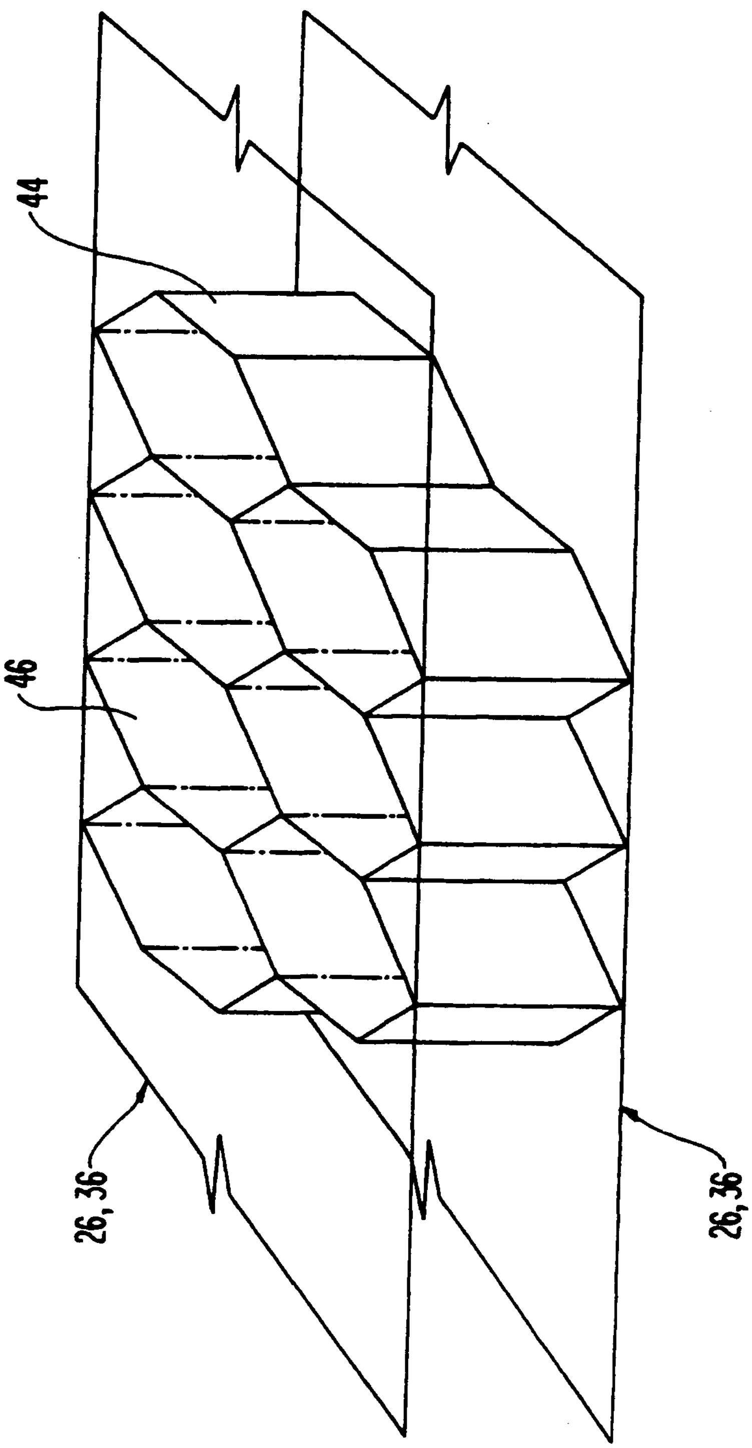


FIG. 9

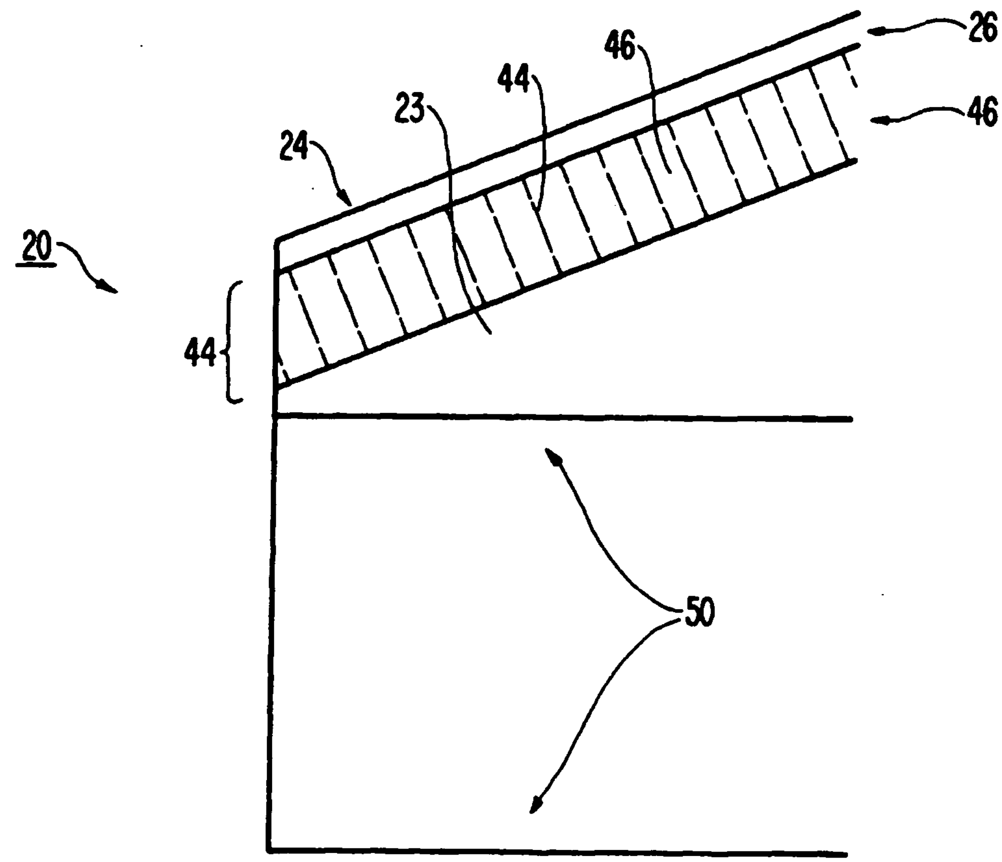


FIG. 10

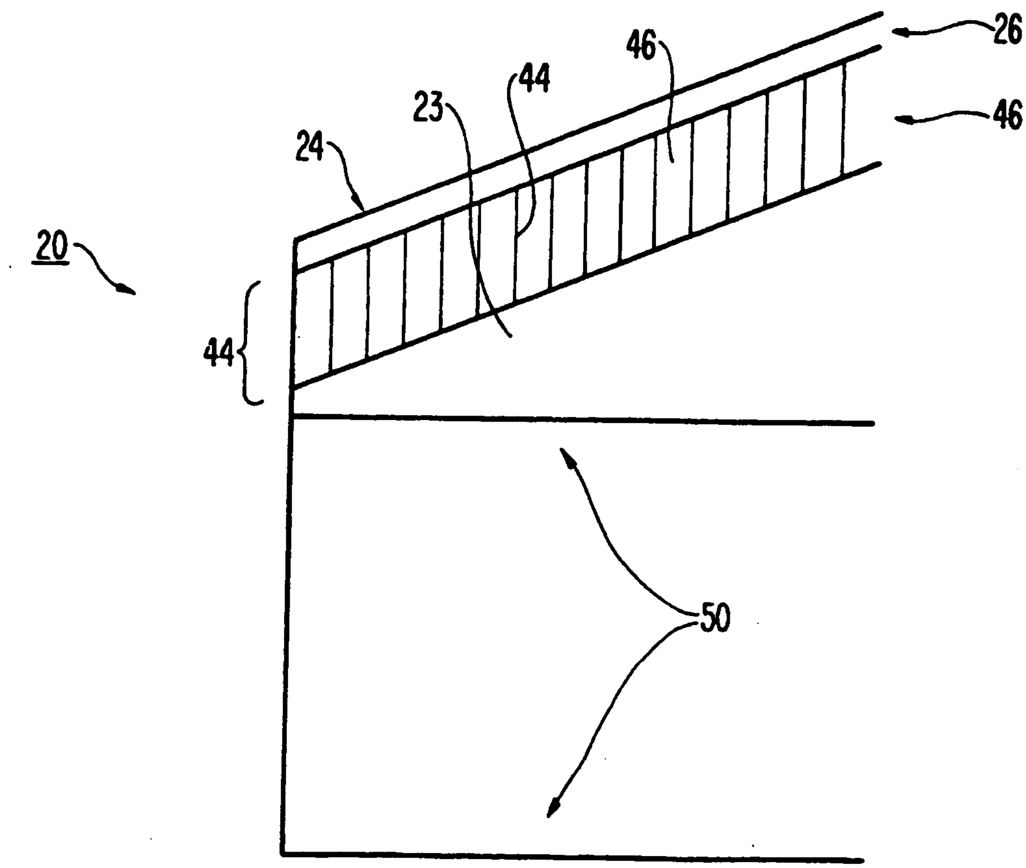


FIG. 11

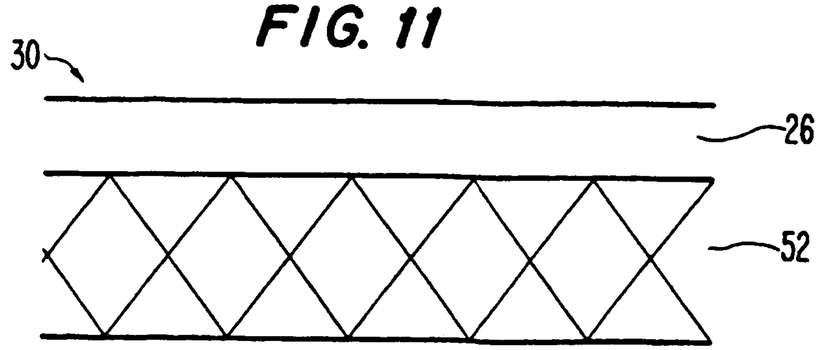


FIG. 12A

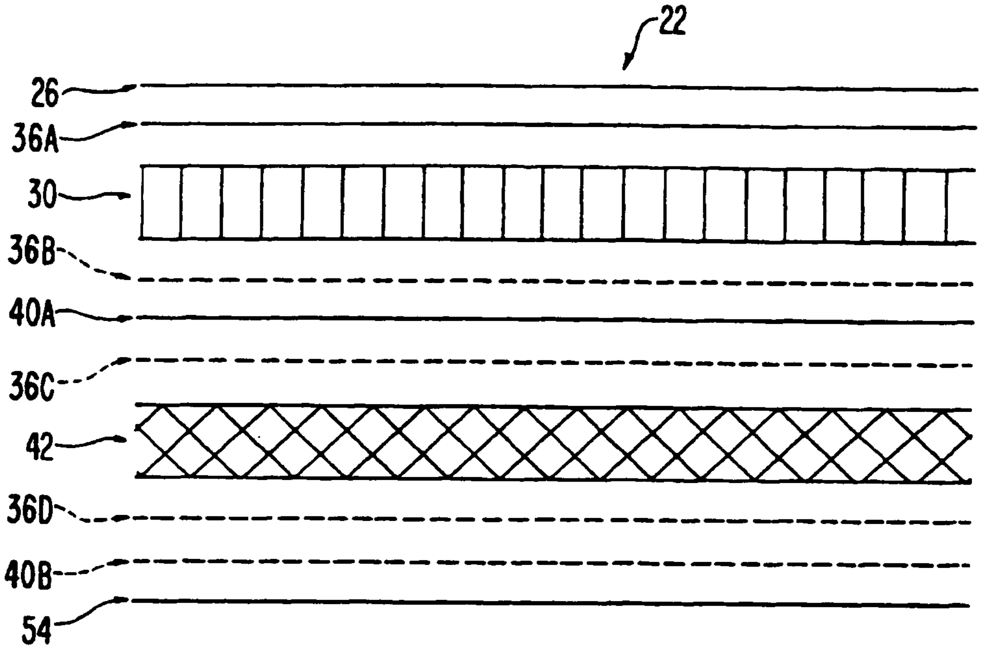


FIG. 12B

NAME OF LAYER	LAYER NUMBER	REFERENCE NO. (FIG. 12A)	OUTSIDE*
GLAZING	1	26	
SHUTTER	2	36A	
TRANSPARENT INSULATION	3	30	
SHUTTER	4	36B	
ABSORBER	5	40A	
SHUTTER	6	36C	
HEAT STORAGE	7	42	
SHUTTER	8	36D	
ABSORBER	9	40B	
INTERIOR FINISH	10	54	

* SCHEMATIC REPRESENTATION OF THE LAYERS. INSIDE

FIG. 13

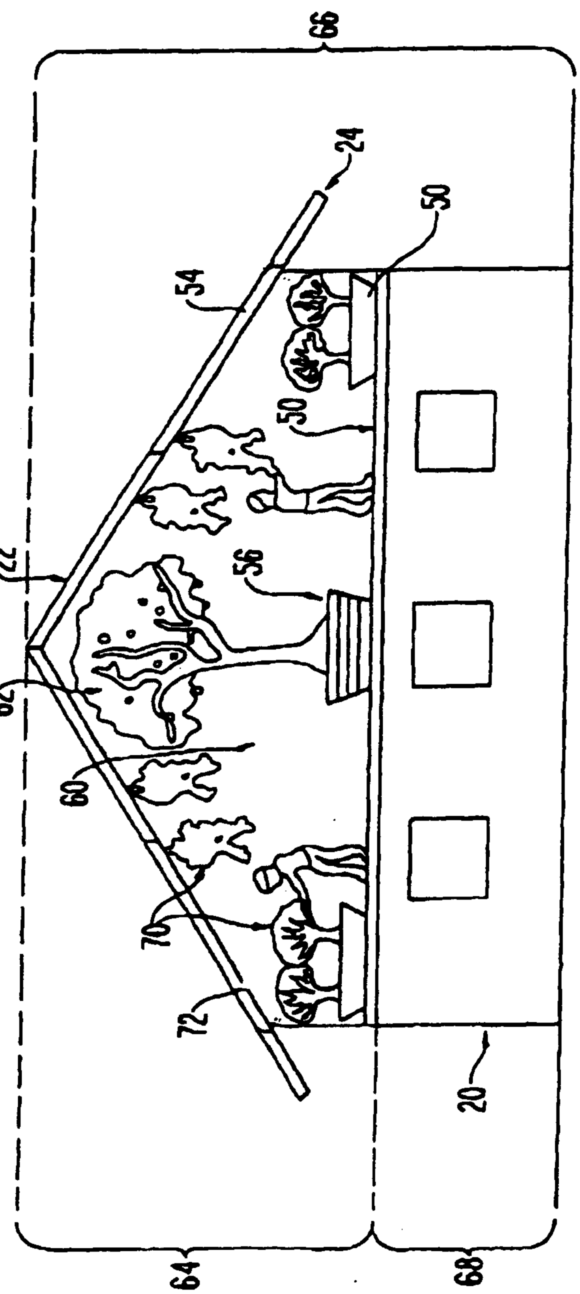


FIG. 14

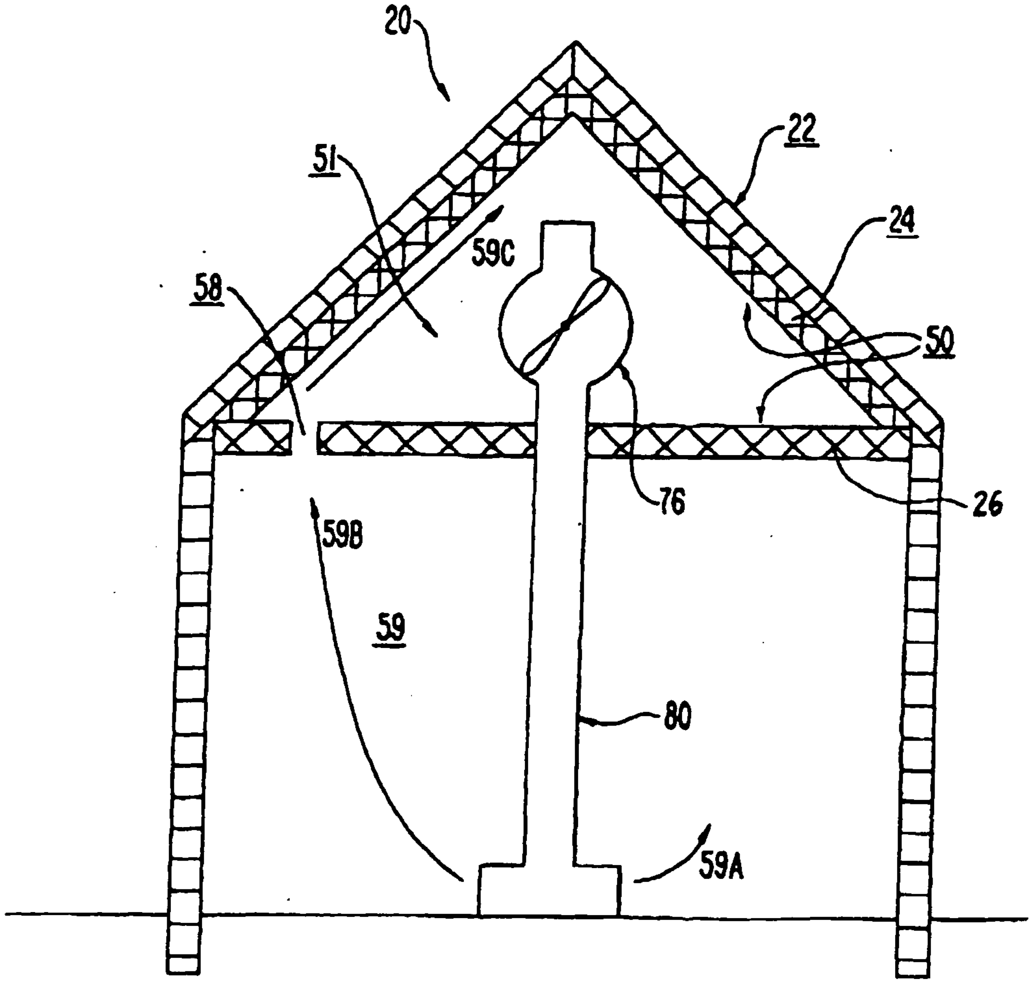


FIG. 15

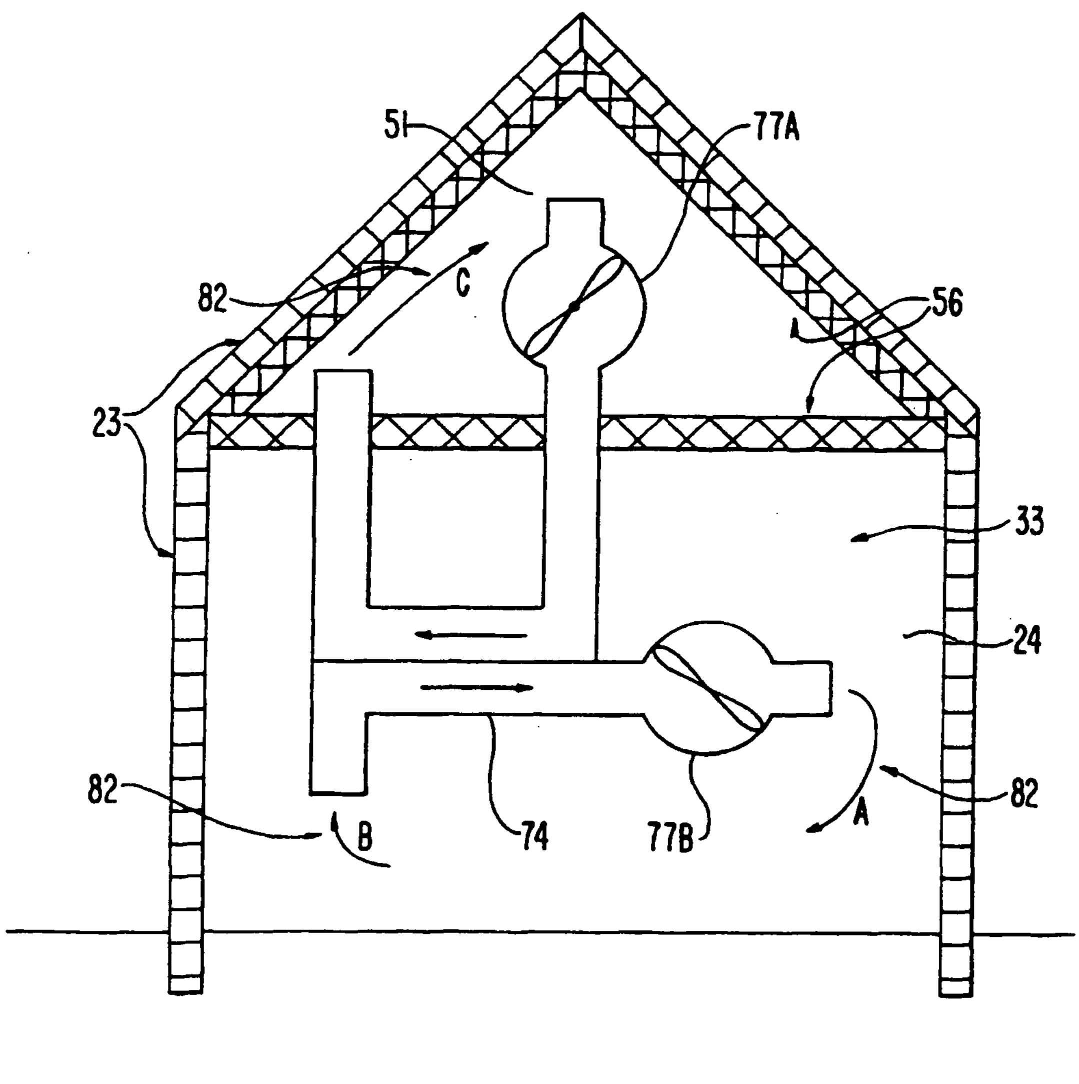


FIG. 16

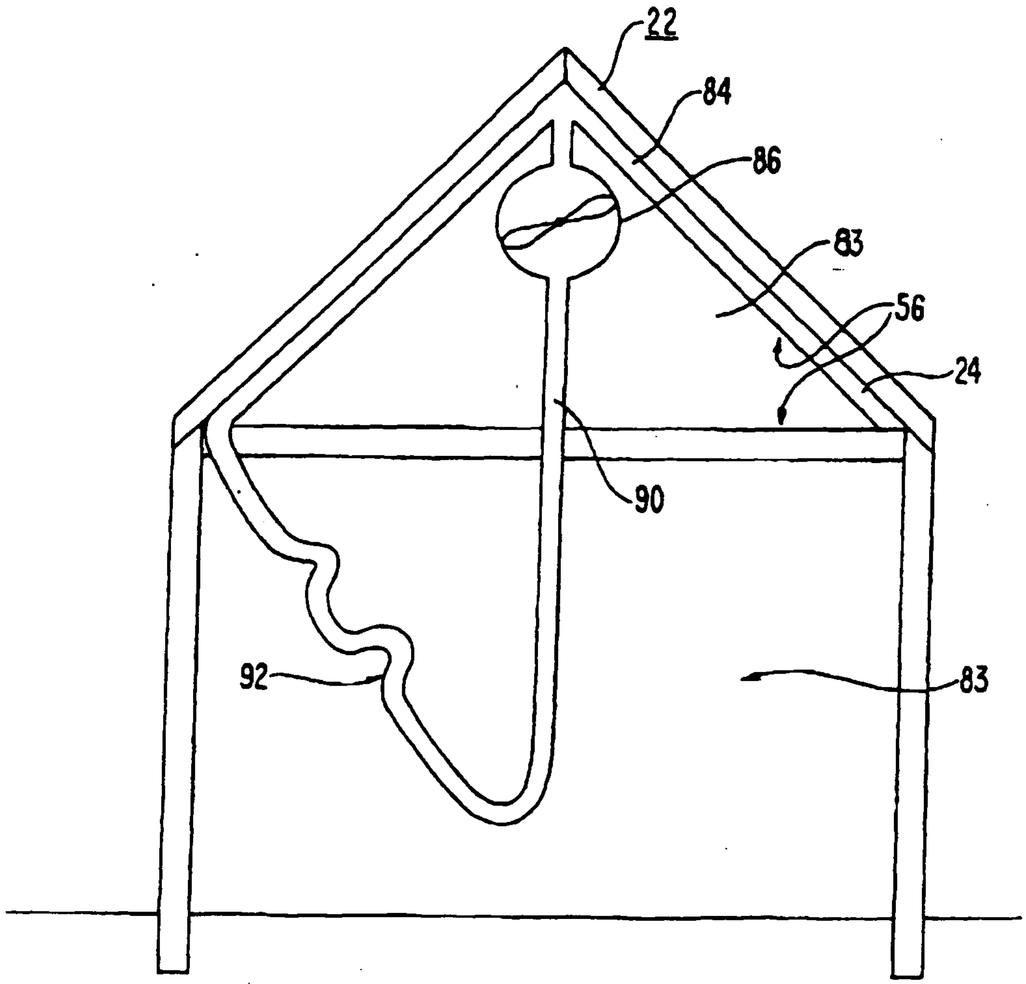


FIG. 18

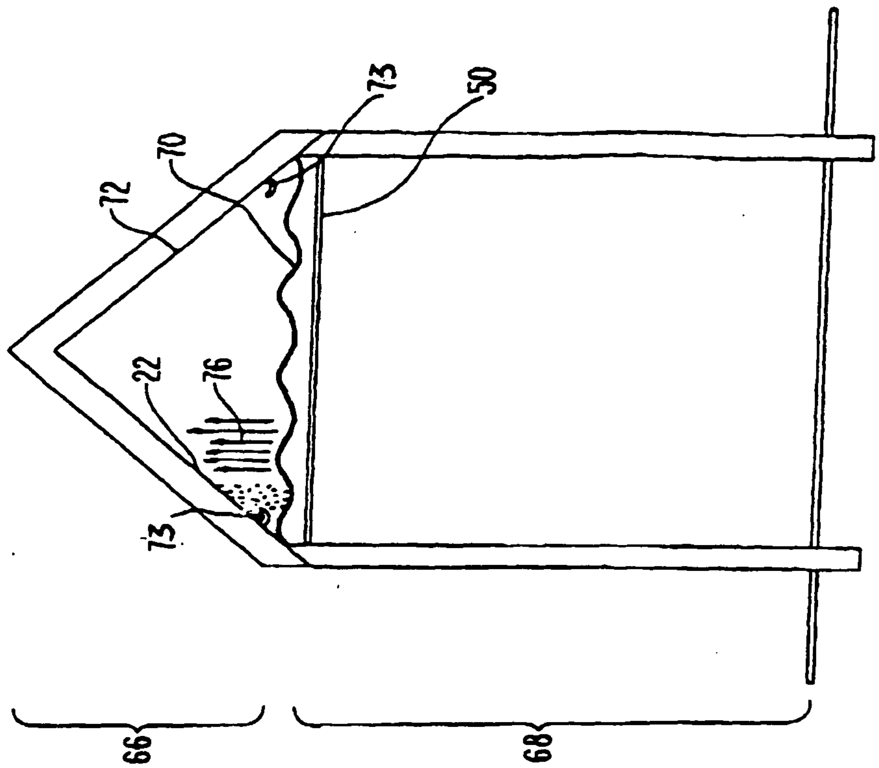


FIG. 17

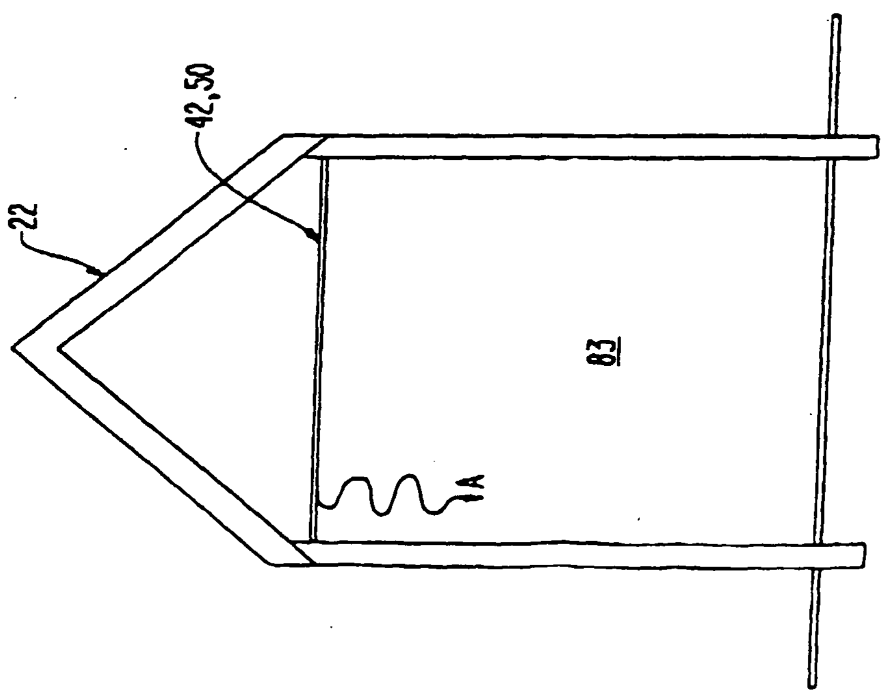


FIG. 19

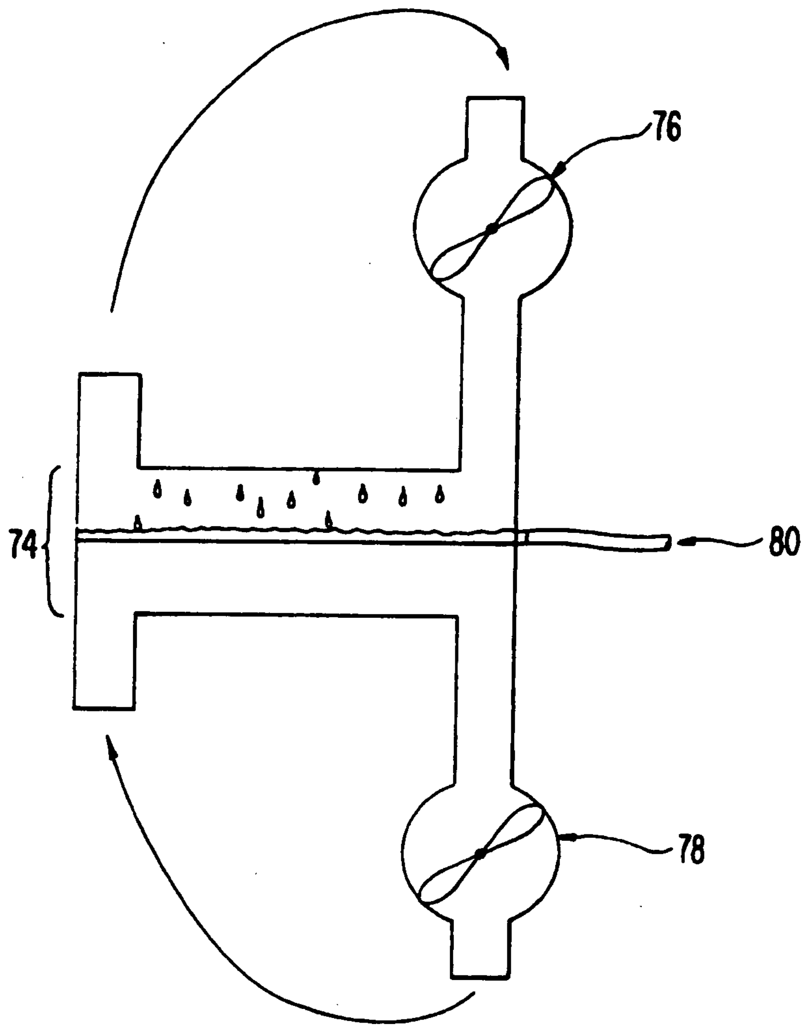
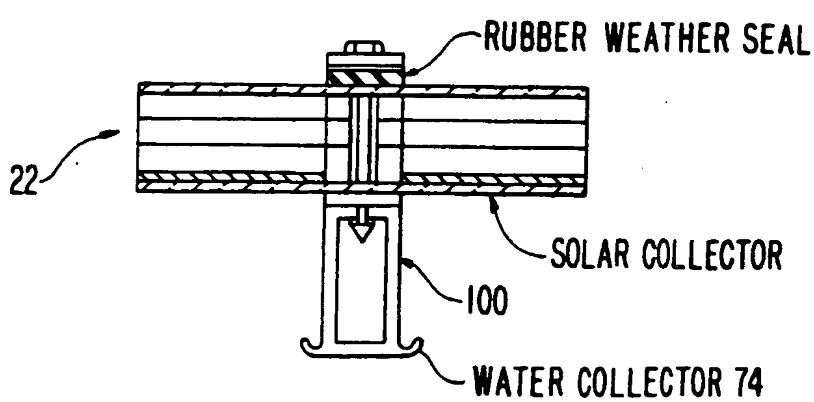

76
74
80
78

FIG. 20


RUBBER WEATHER SEAL
22
SOLAR COLLECTOR
100
WATER COLLECTOR 74